PRODUCTIVITY ENHANCEMENT OF BLACKGRAM (*Vigna mungo* (L.) Hepper) INTERCROPPED IN COCONUT GARDENS

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by

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THESIS

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2021

DECLARATION

I, hereby declare that this thesis entitled **"PRODUCTIVITY ENHANCEMENT OF BLACKGRAM (*Vigna mungo* (L.) Hepper) INTERCROPPED IN COCONUT GARDENS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"PRODUCTIVITY ENHANCEMENT OF BLACKGRAM (*Vigna mungo* (L.) Hepper) INTERCROPPED IN COCONUT GARDENS"** is a record of research work done independently by Ms. Pooja A. P. (2018-21-009) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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POOJA. A. P

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
BCR	Benefit cost ratio
CD	Critical difference
CGR	Crop growth rate
cm	Centimetre
et al	Co –workers/co-authors
DAS	Days after sowing
EC	Electrical conductivity
Fig	Figure
FYM	Farmyard manure
g	Gram
ha	Hectare
ha^{-1}	Per hectare
HI	Harvest index
K	Potassium
KAU	Kerala Agricultural University
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index

m	metre
m^2	Square metre
MAS	Months after sowing
mg kg^{-1}	Milligram per kilogram
mg L^{-1}	milligram per litre
mL	milliliter
mm	Millimetre
N	Nitrogen
NAA	Naphthalene acetic acid
NAR	Net assimilation rate
NS	Not significant
OD	Optical density
P	Phosphorus
PAR	Photosynthetically active radiation
pH	Negative logarithm of H^+ ion concentration
PGR	Plant growth regulator
ppm	Parts per million
RGR	Relative growth rate
RH	Relative humidity
SA	Salicylic acid
SEm(±)	Standard error of means

SLW	Specific leaf weight
TDMP	Total dry matter production
t ha^{-1}	Tonnes per hectare
var.	Variety
viz.,	Namely

LIST OF SYMBOLS

@	At the rate of
®	Registered sign
™	Trade mark sign
° C	Degree Celsius
/	Or
° E	Degree East
° N	Degree North
%	Per cent
±	Plus-minus sign
₹	Rupees

INTRODUCTION

1. INTRODUCTION

Pulses are the basic ingredient in the diets of a vast majority of the Indian population, as they provide vegetarian protein component of high biological value as perfect mix when supplemented with cereals. Pulses are also an excellent feed and fodder for livestock. The unique ability of biological nitrogen fixation, soil amelioration, carbon sequestration, low water requirement and capacity to withstand extreme drought, pulses have remained an integral component of sustainable crop production system (Ali and Gupta, 2012). The short growing period offer a wide scope of crop intensification as they fit to different cropping systems. The ability to utilize atmospheric nitrogen and the potential for improving the cycling of nitrogen, climate-smart nature of these crops, make an important contribution to mitigate climate change besides adapting to climate change.

India, the largest producer and consumer of pulses in the world, have an area of 29.4 mha with an annual production of 19.5 mt and productivity of 664 kg ha^{-1} (DPD India, 2018). In Kerala, pulses are cultivated in an area of 2489.49 ha with a production of 2299.92 t (GoK, 2021). The pulses in general are grown in marginal lands under average management. Among pulses, blackgram (*Vigna mungo* (L.) Hepper) also known as urd bean is a much preferred short duration crop as it survives better in all seasons either as sole crop, intercrop or catch crop accounting for 13 per cent of the total pulse area and 10 per cent of the total pulse production in the country (MoA and FW, 2021).

Cultivation in rainfed condition with poor management, presence of various physiological, biochemical as well as inherent factors including indeterminate growth habit, continuous flowering and fruiting, tough competition for available assimilates between vegetative and reproductive sinks associated with the crop lowers yield potential of blackgram. Apart from this, flower drop and poor pod setting due to flower abscission and lack of nutrients during critical stage of crop growth adds to the threat of lower production per unit area of blackgram (Mahala *et al*., 2001). The declining trend in productivity of blackgram in recent years in India calls for the attention in this crop (Singh and Srivastava, 2021).

Coconut (*Cocos nucifera*), popularly called as Kalpavriksha (Tree of heaven) is one of the major plantation crops in India, third in the world with respect to area and production (GoI, 2019). Coconut planted at a spacing of 7.6 m x 7.6 m offers wide interspace for planting other crops. Increased light transmission in coconut plantations of above 40 years by 50 per cent can be utilized beneficially for growing intercrops that can tolerate a lower extent of shade (Nelliat, *et al.,* 1974). The short duration of blackgram fits the crop to the interspaces of coconut garden.

The selection of suitable varieties and nutrient management practices are never obsolete in enhancing the production as they are among the basic features of agro physiological variation in yields which contribute to the productivity. As the pulse crops are known for having a broad genetic diversity (Lewis *et al*., 2005), can be used for screening more climate-resilient, need based varieties that can be adapted to future climate change scenarios too.

To obtain maximum yield under low light, selection of suitable varieties plays an important role in intercropping. Different varieties respond differently to shading stress in terms of morpho-physiology as well as yield. Availability of suitable varieties with appreciable grain yield and shade tolerance is a common limitation in the popularization of blackgram cultivation in coconut garden (Abraham *et al.,* 1992). To encourage and extend black gram cultivation in the prevailing situation of land fragmentation and low availability of cultivable lands, inclusion of black gram in coconut gardens as an intercrop is one of the practical solutions. Suitable shade tolerant varieties need to be identified for making this solution a reality.

A recent literature review by Swaminathan *et al*. (2021) briefed about the varietal constraints leading to low productivity of blackgram along with other climatic and agronomic constraints and pointed that among fertilizer application practices, foliar application of nutrients is a low-budget, yet effective method. They emphasized the selection of suitable varieties to the situation coupled with foliar application of nutrients and/or growth regulators to improve the productivity of blackgram. Research works on the effect of foliar application of nutrients and growth regulators to enhance the productivity of blackgram intercropped in coconut garden is meagre. Under, shaded or stressed situations, plant growth regulators provide optimum vegetative growth by regulating plant growth and architecture. They also enhance the source-sink relationship and stimulate photo-assimilate translocation thereby helping in effective flower formation, fruit and seed development, ultimately enhancing the productivity of crops.

In this backdrop, the present study is envisaged with the following objectives:

- To identify shade tolerant blackgram varieties suitable for coconut gardens
- To study the effect of foliar nutrition and plant growth regulators on growth and yield of the identified shade tolerant blackgram varieties
- To work out the economics of blackgram cultivation in coconut garden.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Blackgram [*Vigna mungo* L. (Hepper)] or urd bean is one of the important pulse crops which have its origin in India. It is a much preferred crop for all seasons either as sole or as an intercrop in coconut garden. To encourage and extend blackgram cultivation in coconut gardens, suitable varieties tolerant to shade need to be identified. In general, the yield of blackgram is low due to inherent physiological reasons and limited source and poor sink development. Foliar application of nutrients and plant growth regulators (PGRs) were found to increase the yield of blackgram. The current state of knowledge on performance of blackgram and related crops under shade and its effect on growth, yield attributes, yield, quality and the effect of foliar application of nutrients and growth regulators on soil physicochemical properties are reviewed in this chapter.

2.1 EFFECT OF SHADE ON PULSES

Shade, regardless of its source reduces the irradiance predominantly in the photosynthetically active region of the spectrum (400-700 nm). The level of irradiance is a major ecological factor that influences plant growth. In general, pulses are sensitive to reduced light levels and yield reduction by reduced light depends upon crop species as well as degree of shading.

Coconut occupies more than 40 per cent of cultivable area in Kerala, which account for 7.9 lakh ha with a production of 5473 million nuts (GoK, 2019) and it offer an opportunity for intercropping. Morphological and physiological parameters of intercrops varied considerably due to the prevailing partial shaded condition in the coconut garden and hence affecting the yield.

The active root zone of coconut is confined only to 25 per cent of the available land area. So the interspaces of coconut garden can be effectively utilized for growing crops which are suited for that area (Nelliat *et al.,* 1974).

It is well documented that the photosynthetic response of a plant is affected by the light intensity at which it is grown (Valladares *et al.,* 2003). Strong correlations also exist between the yield of a crop and its light environment. Considerable changes in morpho-physiological nature of sun and shaded plants were reported by many workers across the globe. Lower biomass or yield drop by reduced light depends upon crop species as well as degree of shading. Legumes are sensitive to reduced light levels either due to crop combinations or overcrowding (Valizadeh and Shakiba, 2006).

Generally shading occurs due to dense plant population, intercropping, altered planting geometry and excessive vegetative growth which affect the performance through reducing photosynthetic capacity of plants. Adaptive response to low irradiance is higher leaf area, chlorophyll content, leaf to stem ratio and stem length. Grain yield of pulse species has been reported to reduce, when intercropped with cereals and other crops (Liu *et al*., 2017).

The low yield in intercropped pulse species was mainly due to shading that resulted in weak plant growth. The reduction in light reaching the legume canopy when intercropped with other crops was about 30 - 50 per cent of the total incoming radiation and began around 30 - 35 days after seeding of the crops (Armstrong *et al.*, 2008). To obtain the maximum yield of the pulses under low light, selection of suitable pulse species plays an important role in crop mixtures.

According to Kakiuchi and Kobata (2006), the species may respond differently to shading stress in terms of morpho-physiology as well as yield. In particular, photosynthetic active radiation is the major factor regulating photosynthesis and other physiological processes in plants. Hence, the dry matter production and yield depends on it to a greater extent (Lemaire *et al.*, 2007). Selection of pulses that perform stable photosynthesis under different light intensities will be a greater advantage to get high and stable productivity under the natural environment.

2.1.1 Effect of Shade on Growth Characters of Pulses

2.1.1.1 Plant Height

The general effect of plants grown under shade is increased growth of main axis (Duggar, 1903; Ross, 1976). Variations in the plant height of pulse varieties with respect to varying shade had been documented by many workers. Tarilla *et al*. (1977) observed a negative correlation in plant height with shade in cowpea and later George (1982) in red gram and grain cowpea. Significant influence of shade on plant height is also reported by George (1982) in groundnut and blackgram and Krishnankutty (1983) in vegetable cowpea.

Increment in plant height with shade was observed by Lakshmamma and Rao (1996b) in blackgram. Similar results of increment in plant height with shade was documented by Hossain *et al*. (2017) in mung bean. Alagupalamuthirsolai *et al*. (2018) examined the different levels of shade and concluded that 75 per cent shade significantly enhanced plant height. Nair (2020) also stated increase in plant height of green gram under partially shaded coconut garden.

2.1.1.2 Number of Leaves

Attridge (1990) observed that low light intensity will promote a greater number of leaves to expose more photosynthetic area under limited illumination. According to Shivashankara *et al*. (2000), number of leaves produced per plant in betel vine was higher under 35 and 60 per cent light compared to 10 per cent light intensity. Vendramini *et al*. (2002) stated that leaf characteristics, *viz*., leaf number and assimilatory area may change in response to important environmental factors including light. Kong *et al*. (2016) observed that differences in light intensity affect the external morphology of leaves, internal anatomy and physiological characteristics.

2.1.1.3 Nodule Activity

In a field study with soybean, Wahua and Miller (1978) observed that shading accelerated rate of loss of nodule activity. The total nodule activity was highest at 20 per cent shade (99.3 klux) and decreased curvilinearly with increase in shade. Trang and Giddens (1980) examined four shading treatments (0, 18, 40 and 62%) in soybean and reported that plants with no shade produced higher number of nodules (25 per plant) and nodule mass (52 mg per plant) than shaded plants. Rao and Ghildiyal (1985) observed a reduction in nodulation in mung bean plants grown under low light in mung bean (40% sunlight).

2.1.1.4 Leaf Area

Cooper and Qualls (1967) recorded 25 per cent increase in the ratio of leaf area to leaf weight with shading in legumes which was associated with changes in leaf morphology. Schoch and Santos (1974) stated that shading increased leaf area in *Vigna sinensis*. Effect of shading on leaf characteristics was studied by Crookston *et al.* (1975) and reported that shading in beans reduced leaf area, number and thickness. Tarilla *et al.* (1977) observed improved plant growth in terms of leaf area under high light intensity. Plants that grow in shady environment invest relatively more of the products of photosynthesis and other resources in leaf area to increase light harvesting and photosynthetic surface (Lambers *et al.*, 1998).

Oritani (1978) studied the effect of light intensity in the contrasting varieties of soybean and found that leaf area was reduced in variety Harosoy grown under reduced light intensities but increased for the variety Tosam upto 90 per cent shade.

Generally, the increase of leaf area with shading is one of the way to increase photosynthetic surface, ensuring a more efficient yield in low light intensities and consequently, compensating the low photosynthetic rate per unit leaf area, a characteristic of shaded leaves (Hadi *et al.*, 2006). According to Manoj *et al.* (2019), shading at 50 and 75 per cent of the full sunlight had significant negative effect on leaf area index of pulses over full sunlight. The shaded plants had greater radiation use efficiency than the unshaded and shading reduced the availability of radiant energy at the canopy surface.

2.1.2 Effect of Shade on Physiological Characters

Cooper and Qualls (1967) stated that shaded leaves of legumes contained more chlorophyll per unit leaf weight but less chlorophyll per unit leaf area than in sun leaves. Bowes *et al.* (1972) recorded decreased photosynthetic rate and RuBP carboxylase activity under low light intensity in soybean. Adedipe and Ormrod (1975) observed that cowpea cultivars grown at 10 klux had more leaf area and chlorophyll content than the cultivars grown at 20 klux. Oritani (1978) illustrated decreased photosynthetic activity in soybean cv. Harasoy with reduction in light intensity. Sivakumar and Virmani (1984) found that low light caused reduction in photosynthetic rate at three growth stages studied in four groundnut varieties.

Hadi *et al*. (2006) recorded increased leaf area index, specific leaf weight, leaf area ratio and days to physiological maturity with increased shade level of 55 per cent in common bean. Higher radiation use efficiency (79%) in intercropped beans under reduced light than that of sole crop was documented by Sandana and Calderini (2012). Araki *et al*. (2014) studied the impact of shading on growth and photosynthetic efficiency in green gram and concluded that plants grown under shade showed an increased amount of chlorophyll content per unit leaf area. Alagupalamuthirsolai *et al*. (2018) stated that shade treatment significantly reduced specific leaf weight and increased chlorophyll content in 75 per cent shade.

2.1.3 Effect of Shade on Yield Attributes and Yield

Strong correlations exist between yield of a crop and its light environment (Shibles and Weber, 1965). Subhadrabandhu *et al*. (1978) observed that shading at maturity period in common bean resulted in reduction in number of pods, total dry weight and seed yield.

Wahua and Miller (1978) studied the effect of different levels of shading on soybean and stated that the dry weight of plant tops were the highest at 20 per cent shade and decreased curvilinearly as shading increased. They also reported that number of pods per plant, leaf nitrogen content, total stem nitrogen and grain yield were highly correlated with shading.

Clifford (1979) observed that beans grown in full sun light had more fruit number and seed weight than the plants grown under dim light and he concluded that there is a source limitation of sink yield in mung beans. Increased dry matter in soybean with no shade compared to shaded condition was reported by Trang and Giddens (1980). Liyanage and Mc William (1981) reported that in mung bean, increasing level of continuous shade produced a linear decrease in seed yields. The adverse effect was most pronounced on the number of pods per plant followed by number of seeds per pod and seed size. The yield reduction was proportionate to the duration and intensity of the shade.

Sampath and Kulandaivelu (1983) noted lower fresh weight and dry weight per unit leaf area of mung beans with progressive decrease in light intensity (33% and 9% of full sun light). Sivakumar and Viramani (1984) observed decrease in total dry matter, yield and yield parameters like number of mature pod, peg number, potential pod bearing zone, shelling percentage and 100 seed weight of groundnut under low light. Later, Rao and Ghildiyal (1985) found that 60 per cent shading resulted in less dry matter production in bean plants compared to control. They also recorded more seed yield in control plants which was kept under full sunlight (7.0 g per plant) than in plants under low light (3.27 g per plant) on mung bean.

Manoj *et al.* (2019) concluded that shading at both 50 and 75 per cent of full sunlight had significant negative effect on total dry matter production of pulses over full sunlight.

2.1.4 Effect of Shade on Quality Characters

George (1982) observed no significant effect in protein content and protein yield due to shade in blackgram and cowpea. Reduced protein and increased oil contents under 50 per cent shade was reported in soybean by Bellaloui (2012).

2.1.5 Effect of Shade on Soil Physico-chemical Properties

Soil nutrient analysis under shade revealed that, there was an increase in the soil nutrient status after experiment with an increase in shade intensity in sword bean (Geetha, 2004). Shading helps in better moisture retention leading to a higher soil organic matter breakdown and, therefore, more nitrogen is available in the soil (Kariuki *et al*., 2018).

Effects of shade on phosphorus acquisition in cereal-legume intercropping systems were studied by Whitehead and Isaac (2012) and measured higher extractable P in rhizobox soils under the shade treatment. Soil characteristics under legume and non-legume tree canopies in signalgrass (*Brachiaria decumbens*) pastures was observed by Dubeux *et al*., (2014) and recorded increased microbial activity under tree shade compared to full-sun soil.

2.1.6 Effect of Shade on Nutrient Uptake

The nutrient uptake studies under different shade intensities indicated that, there was an increase in the uptake of N, P and K with shade intensities. The highest uptake was observed under 50 per cent shade in arrowroot (Geetha, 2004).

2.2 EFFCT OF FOLIAR APPLICATION OF NUTRIENTS ON PULSES

Subramanian and Palaniappan (1981) stated that foliar application of major nutrients like N and K was found to be as good as soil application. Syriac *et al.* (1988) observed that grain yield can be increased by the combined application of N and P partly through soil and partly through foliar application in blackgram. Salim (1992) concluded that application of nutrient elements through foliar spray at appropriate stages of growth is important for their efficient utilization and better performance of the crop. Foliar nutrients usually penetrate the leaf cuticle or stomata and enters the cells facilitating easy and rapid utilization of nutrients (Latha and Nadanassababady, 2003).

Manonmani and Srimathi (2009) reported that foliar application increased the yield from 12 to 25 per cent and it was found to be 20 times more effective than soil applied fertilizers. Foliar application is credited with the advantage of quick and efficient utilization of nutrients, elimination of losses through leaching and fixation and regulating the uptake of nutrients by plants. Reddy *et al.* (2010) pointed that foliar spray of macronutrients is the most important factor determining the yield. It stands as one of the effective and convenient method of nutrition as it facilitates quick and easy absorption through stomatal openings or cuticles which may result in quick and efficient response (Kannan, 2010).

2.2.1 Effect of foliar spray of 19:19:19

All 19 (19:19:19 NPK) is a 100 per cent water soluble product which can be used in drip fertigation or as foliar spray which contain nitrogen, phosphorus and potassium in equal proportion. Being a good source of all the three macro nutrients, it helps the crop to meet the major nutrient requirement.

2.2.1.1 Effect on Growth Characters

Rajesh (2011) reported that foliar application of polyfeed (19:19:19) and 1 per cent multi K recorded higher plant height in red gram. Mamathashree *et al*. (2014) observed that foliar application of water soluble fertilizer 19:19:19 at 2 per cent concentration at peak flowering and pod development stage recorded higher plant height, primary branches at harvest and leaf area in pigeon pea.

Mallesha *et al.* (2014) recorded higher plant height, number of branches and leaf area with application of 1 per cent 19:19:19 at peak flowering, pod development and at pod filling stage in pigeon pea. Gowda e*t al.* (2015) studied the response of pigeon pea in terms of soil application of micronutrients and foliar spray of macronutrients on yield and revealed that soil application of $ZnSO_4$ @ 25 kg ha^{-1} along with foliar spray of 19:19:19 (0.4%) resulted in significantly higher growth attributes. Kumar *et al.* (2018) recorded maximum root length (18.50 cm) with the application of 19:19:19 (NPK) 2 per cent spray at flowering at 60 DAS. Mudalagiriyappa *et al.* (2016) reported that foliar application of 19:19:19 @ 1.5 per cent at flowering and pod development stage along with the basal application of fertilizers significantly increased growth attributes in greengram. Karthikeyan *et al.* (2020) found that foliar spray of pulse wonder (1%) with 19:19:19 significantly influenced root nodule number (29.4) and also nodule dry weight (0.29 g per plant) in blackgram.

Banasode and Math (2018) observed significantly higher number of branches per plant (5.20) with two foliar sprays of 19:19:19 (1%) in soybean. The foliar application of 2 per cent 19:19:19 at flowering stage recorded the highest plant height of 24.27 cm (Bochalya *et al.*, 2021).

2.2.1.2 Effect on Physiological Characters

Kumar *et al.* (2018) reported that application of 2 per cent concentration of 19:19:19 at flowering stage produced maximum crop growth rate (CGR) of 35.42 g m^{-2} day^{-1}) and relative growth rate (RGR) of 0.066 g^{-1}g^{-1} day^{-1} during 45-60 days interval in blackgram. Karthikeyan *et al*. (2020) found that the foliar nutrition has significantly influenced the growth indices *viz*., absolute growth rate (AGR), CGR and leaf area duration (LAD) at all growth stages. Among the treatments, foliar spray of pulse wonder (1%) with 19:19:19 registered a maximum value of AGR (0.796 and 0.805 g per day) at flowering and pod development.

2.2.1.3 Effect on Yield Attributes and Yield

Rajesh (2011) documented significantly higher number of pods per plant, pod weight and grain yield with the foliar application of polyfeed (19:19:19) and 1 per cent multi potassium. Mallesha *et al.* (2014) studied the effect of five concentrations of water soluble fertilizer NPK (19:19:19) *viz.*, no foliar spray (control), 0.25, 0.5, 0.75 and 1.0 per cent at peak flowering, pod development and at pod filling stage and revealed that foliar application of 1.0 per cent 19:19:19 recorded higher number of pods per plant (121.8), pod weight per plant (105.5 g), grain yield per plant (19.9 g) and grain yield (1661 kg ha^{-1}). They also recorded higher total dry matter production at harvest with the foliar application of 1.0 per cent 19:19:19.

Mamathashree (2014) reported significantly higher seed yield (1272 kg ha^{-1}), total dry matter production (142.8 g per plant), higher gross returns (₹ 53431 ha^{-1}), net returns (₹ 33976 ha^{-1}) and BC ratio (2.7) with foliar application of water soluble fertilizer 19:19:19 at 2 per cent concentration as compared to other soluble fertilizers. The increase in yield can be attributed to the higher availability of assimilates with foliar spray of water soluble fertilizers. Significant differences in the seed yield of pigeon pea with foliar spray of water soluble fertilizers might be attributed to improved growth and yield components *viz.*, total dry matter production and its distribution into different plant parts, number of branches per plant, number of pods per plant, seed weight per plant and 100 seed weight. Kumar *et al.* (2018) found that application of 2 per cent 19:19:19 twice at flower initiation and pod formation produced higher seed and haulm yield in blackgram. Singhal *et al*. (2015) stated that foliar application of the combination of nutrients improved the source sink relationship triggering and increased the number of pods per plant in vegetable cowpea.

Gowda *et al*. (2015) opined that the application of zinc sulphate @ 25 kg ha^{-1} along with foliar spray of 19:19:19 @ 0.4 per cent in pigeon pea at flower initiation and pod development stage recorded higher seed yield of 1390 kg ha^{-1} and haulm yield of 3421 kg ha^{-1} compared the control. Das and Jana (2015) reported that application of 19:19:19 (3%) spray recorded the highest seed yield of 1000 kg ha^{-1} and 1162 kg ha^{-1} in greengram and blackgram respectively.

Singhal *et al*. (2015) observed higher number of pods per plant, commercial pods yield, yield per plant, dry seed yield and dry plant yield by foliar spray of NPK (19:19:19) @ 0.5 per cent on vegetable cowpea. Jadhav and Kulkarni (2016) reported ha foliar spray of 19:19:19 @ 1 per cent on greengram recorded significantly higher grain yield (1121 kg ha^{-1}).

According to Mudalagiriyappa *et al.* (2016) foliar spray of water soluble fertilizer (19:19:19) at 1.5 per cent concentration at flowering and pod development stage along with basal application of fertilizers (13.5: 25: 25 kg N, P_2O_5, K_2O) significantly increased growth attributes, yield and benefit cost ratio in chickpea cultivation. Jadhav and Kulkrani (2016) reported significantly higher grain yield during both years of study (1121 and 1105 kg ha^{-1}) in green gram with foliar spray of 19:19:19 @ 1 per cent at flower initiation stage.

El-Azab (2016) reported that foliar application of NPK (19:19:19) compound with Fe, Zn and Mn at different doses increased in vegetative growth, yield and its components and nutrient concentration of cowpea plant compared with control. Kulkarni *et al.* (2016) found significantly higher grain yield (644.2 kg ha^{-1}) with the foliar spray of panchagavya and 19:19:19 in greengram. Application of 19:19:19 (NPK) 2 per cent spray at flowering stage recorded higher grain yield (870 kg ha^{-1}) and net returns (₹ 20108 ha^{-1}) in blackgram. The increase in yield might be due to enhanced yield attributes like number of pods per plant and number of seeds per pod. It may also be due to increased uptake of nutrients by blackgram by effective translocation of nutrients from sink to reproductive area of crop (Kumar *et al.*, 2019).

Banasode and Math (2018) observed that two foliar sprays of 1.0 per cent NPK (19:19:19) resulted in significantly higher total dry matter production in soya bean. Patel (2018) noted higher seed yield (1361 kg ha^{-1}) with foliar spray of NPK (19:19:19) 2 per cent at flower initiation. Kumar and Simainya (2019) recorded the highest number of pods per plant, number of seeds per pod and seed index with the spray of 2 per cent 19:19:19 (NPK) at flowering. This might be due to better absorption of nutrients applied through foliage leading to better activity of functional root nodules resulting in more leaf area, dry matter production and uptake of nutrients. This could have led to more flower production and subsequently pod formation and other yield attributing characters. The increased 100 seed weight might be attributed to increased mobilization of metabolites to the reproductive sinks. Yalagar *et al.* (2021) reported that, application of recommended nutrients to pigeonpea coupled with foliar spray of 19:19:19 at 1 per cent + vermiwash at 10 per cent at flower initiation and peak flowering stage was optimum for higher grain yield (1592 kg ha^{-1}), higher net returns (₹ 65908 ha^{-1}) and BC ratio (3.49). A significant increase in yield parameters was mainly due to increased nutrient uptake and improved growth parameters. The supply of nutrients through foliar application increased the nutrient assimilation and better utilization by the crop, which in turn produced more photosynthates resulting in better partitioning of dry matter from source to sink. Foliar nutrition preferentially increased the metabolic processes like photosynthesis, enhanced nucleic acids, soluble proteins and carbohydrates, which resulted in higher dry matter production and sink size.

2.2.1.4 Effect on Quality Characters

Gowda *et al*. (2015) reported that the foliar spray of 19:19:19 at 0.4 per cent recorded significantly higher protein content (22.47%) and protein yield (288.75 kg ha^{-1}) in pigeon pea.

2.2.1.5 Effect on Soil Physico-chemical Properties

Shruthi and Vishwanath (2018) observed that the application of water soluble NPK fertilizers (19:19:19) did not have any marked influence with respect to the soil properties as well as available nutrients in lima bean.

2.2.1.6 Effect on Nutrient Uptake

El-Azab (2016) reported that the effects of foliar application of NPK (19:19:19) increased N, P and K concentration and uptake in cowpea. Mudalagiriyappa *et al*. (2016) recorded significantly higher N and K uptake (98.5 kg ha^{-1} and 81.8 kg ha^{-1} respectively) with foliar application of water soluble fertilizer 19:19:19 (1.5%) at flowering and pod development stage along with the basal application of fertilizers in greengram. Shruthi and Vishwanath (2018) reported that foliar fertilization of water soluble NPK fertilizers (19:19:19) improved uptake of the primary nutrients in lima bean.

2.2.2 Effect of foliar spray of Sulphate of Potash

Sulphate of potash (SOP), having the chemical formula K_2SO_4 is a 100 per cent water soluble fertilizer which contain 50 per cent K_2O and 17.5 per cent sulphur. It imparts pest and disease resistance and is used in sink filling and proper ripening. The response for foliar application of SOP was more than soil applied K and the yield increase can be attributed to the effect of sulphur also (Sadasivam *et al.*, 1990; Ravichandran *et al.*, 1997).

2.2.2.1 Effect on Growth Characters

Foliar application of sulphate of potash could partially replace the soil application (Surendran, 2000; Ali *et al*., 2007). Mamathashree *et al.* (2014) stated that foliar spray of SOP resulted in higher growth attributes in pigeon pea.

2.2.2.2 Effect on Physiological Characters

Sadasivam *et al.* (1990) observed higher photosynthetic rate due to foliar spraying of SOP (1%) in greengram. Sathyamoorthi *et al*. (2008b) reported higher photosynthetic rate with the application of 125 per cent NP along with foliar spraying of DAP (2%) and SOP (1%) twice at 25 and 45 DAS in green gram.

2.2.2.3 Effect on Yield Attributes and Yield

Babu *et al*. (1985) recorded significant increase in seed yield by 12.2 per cent with foliar spray of SOP (1%) in blackgram. Sadasivam *et al.* (1990) observed an increase in productivity of greengram with foliar spraying of SOP (1%). The response for foliar application of SOP was more than soil applied K. Ramamoorthy *et al.* (1995) compared foliar and/or basal applications of N, P and K on blackgram. Foliar application of 1 per cent K_2SO_4 + basal applications of N + P produced the seed yield of 536 kg ha^{-1}.

Sathyamoorthi *et al.* (2008a) reported higher yield characters *viz.,* pods per plant, pod length, seeds per pod and seeds per plant with 125 per cent NP along with foliar spraying of DAP (2%) and SOP (1%) twice. Gowda *et al*. (2015) reported that in pigeonpea foliar spray of 0:0:50 at 0.3 per cent recorded higher seed yield (1252 kg ha^{-1}) and stalk yield (3429 kg ha^{-1}).

Mulagund *et al*. (2015) concluded that the combined foliar sprays of 2 per cent SOP and 2 ppm brassinosteroid significantly increased the bunch characteristics and fruit yield in Banana. Soil application of sulphur @ 20 kg ha^{-1} as K_2SO_4 coupled with recommended dose of fertilizers and 0.5 per cent as SOP foliar spray at 30 and 45 DAS showed significantly better response in blackgram (Gokila *et al.,* 2017).

2.2.2.4 Effect on Quality Characters

Application of sulphur @ 20 kg ha^{-1} along with 0.5 per cent SOP foliar spray plus 100 per cent recommended dose of fertilizers recorded the highest protein content of 23.0 per cent in blackgram (Gokila *et al.,* 2017). Soil application of 40 kg ha^{-1} of sulphate of potash recorded the highest quality parameters *viz.,* starch, vitamin C and protein in greengram variety VBN 2 (Karthiyekan *et al.,* 2020).

2.2.2.5 Effect on Soil Physico-chemical Properties

Sathyamoorthi *et al*. (2008a) recorded higher soil available N, P and K in green gram with the application of 125 per cent NP along with foliar sprays of DAP (2%) and SOP (1%) twice at 25 and 45 DAS.

2.2.2.6 Effect on Nutrient Uptake

Higher N, K and S uptake by greengram with the application of 125 per cent NP along with foliar sprays of DAP (2%) and SOP (1%) twice at 25 and 45 DAS was recorded by Sathyamoorthi *et al*. (2008b). Gokila *et al.* (2017) observed that the NPK uptake in blackgram was significantly higher for the application of sulphur (20 kg ha^{-1}) along with 0.5 per cent SOP foliar spray plus 100 per cent recommended dose of fertilizers.

2.3 EFECT OF FOLIAR APPLICATION OF PLANT GROWTH REGULATORS

The plant growth regulators are the chemical substances when applied in small amounts, bring rapid changes in the phenotypes of the plant and also influence the plant growth, right from seed germination to senescence either by enhancing or by stimulating the natural growth regulatory system. It might increase the crop productivity by increasing the photo-assimilate partitioning and translocation thereby enhancing source- sink relationship (Taiz and Zeiger, 2003). They also stimulates and influences a number of parameters from alteration of plant architecture, photo-assimilate partitioning and various physiological and metabolic processes as suggested by Sharma *et al.* (2013).

2.3.1 Effect of Naphthalene Acetic Acid (NAA)

NAA, 1- Naphthalene acetic acid is a naphthalene derivative with the formula $C_{10}H_7CH_2CO_2H$ having a molecular weight of 186.21 g mol^{-1}, used as a synthetic plant growth stimulator and is applied as a spray with a concentration of 20 to 100 mg L^{-1} depending on target plants. It is used as a growth regulator to increase flower production, reduce flower drop and increase grain yield in pulses.

Foliar application of NAA promotes the apical dominance, cell elongation and shoot development.

2.3.1.1 Effect on Growth Characters

Pandey (1975) observed significant increase in plant height, number of branches and flowers in pigeonpea with the spray of 20 ppm NAA during flowering stage. Nooden *et al*. (1979) noticed delayed senescence in soybean with the application of NAA. Merlo *et al.* (1987) recorded significant increase in number of branches per plant and dry matter in soybean with the application of NAA. Kelaiya *et al.* (1991) reported an increased LAI and plant dry weight in groundnut by applying NAA, tricontanol and cycocel (CCC). Baghel and Yadava (1994) found significantly higher plant height in blackgram with the application of 30 ppm NAA compared to control. Lakshmamma and Rao (1996b) recorded significantly higher plant height in blackgram due to foliar application of NAA 20 ppm at 50 per cent flowering and one week later in shade. Shinde and Jadhav (1995) observed increased leaf area in greengram with the foliar application of NAA (50 ppm).

Dhopte and Suradkar (1998) reported that the number of root nodule was not affected by growth regulators like gibberellic acid and NAA (20 ppm each). Reddy (2002) observed significant increase in plant height, dry matter in leaf, stem and reproductive parts and total dry matter due to application of NAA 40 ppm in chickpea. Das and Prasad (2003) observed that two sprays of NAA at 20 or 40 ppm significantly increased the growth characters like number of leaves and branches of summer mungbean. The total number of nodules and effective nodules were higher due to the application of NAA at 40 ppm (Resmi and Gopalkrishanan, 2006). Thakare *et al*. (2006) stated that foliar spray of NAA with DAP significantly increased number and dry weight of root nodules, dry weight of shoot, plant height, leaf area and total dry matter production. Bhosle *et al*. (2007) recorded a significant increase in plant height and leaf area of blackgram due to the application of NAA at 40 ppm. Jeyakumar *et al*. (2008) observed that foliar application of NAA at 40 ppm at pre flowering stage in blackgram *cv*. LBG 645 significantly increased the plant height (30.1 cm) compared to control (26 cm). Foliar spray of NAA (20 ppm) recorded higher leaf area and LAI compared to growth retardants at 60 and 75 DAS in blackgram (Girisha, 2010).

Ramesh and Ramprasad (2013) studied the effect of NAA on growth parameters and reported significantly higher plant height, number of branches and number of trifoliates leaves per plant with the application of NAA (20 ppm) in soybean.

Shashikumar *et al.*(2013) found higher growth components such as plant height (37.11 cm), number of branches (8.27 per plant), LAI (4.18), LAD (60.45) and total dry matter production (15.98 g per plant) with the application of RDF + foliar spray of 40 ppm NAA + 0.5 per cent chelated micronutrient + 2 per cent DAP in blackgram. Similarly maximum plant height, under foliar spray of NAA t 40 ppm was recorded by Mahajan (2014) in soybean.

Medhi *et al.* (2014) reported highest number and dry weight of nodules per plant at 55 and 75 DAS due to application of 20 ppm NAA in green gram. The significantly highest plant height, leaf area and number of leaves per plant were recorded with application of NAA 20 ppm in soybean (Upadhyay and Ranjan, 2015). Esther and Gautam (2020) reported that combination of recommended dose of fertilizers (25:50:25 kg NPK ha^{-1}), urea at 2 per cent and NAA at 40 ppm resulted in higher growth attributes such as plant height (63.63 cm), number of branches (31.13), root nodules (23.73) and plant dry weight (51.71 g) in blackgram variety T9. The increased value for root nodules of the plant with foliar application can be attributed to the fact that nutrients enhance plant vigour and strengthen the stalk.

2.3.1.2 Effect on Physiological Characters

Kalarani (1991) observed that the foliar application of 1 per cent urea and 50 ppm NAA significantly influenced the specific leaf area in soybean. Dhopte and Suradkar (1998) studied the effect of hormones (GA and NAA 20 ppm each) in soybean and found that NAA was more effective than GA whereas chlorophyll content was not affected by growth regulators.

Grewal and Gill (1986) observed that foliar application of NAA and nitrogen significantly enhanced the photosynthetically active radiation. Nawalagatti *et al.* (1991) reported that the application of growth regulator (NAA at 20 ppm) increased NAR significantly in groundnut. Further there was increase in LAI, NAR and CGR in groundnut cv. DH-3-30 with the foliar application of 10 ppm NAA at 45 days after sowing. Bhagel and Yadava (1994) found that NAA was superior to GA_3 and IAA in enhancing LAI, NAR and CGR in blackgram.

Baghel and Yadava (1994) observed significantly increase in NAR with the foliar application of 40 ppm NAA in blackgram. Rajamohan (1989) and later Shinde and Jadhav (1995) reported that foliar application of 20 ppm NAA increased the SLW in soybean and cowpea.

Shinde and Jadhav (1995) indicated that foliar application of 20 ppm NAA significantly increased chlorophyll content in cowpea. Lakshmamma and Rao (1996a) reported that application of NAA @ 20 ppm at 50 per cent flowering stage increased the chlorophyll content in blackgram. Foliar application of 40 ppm NAA at flower initiation stage significantly increased the CGR at pod filling stage (Ganapathy *et al.*, 2008).

Deotale *et al.* (2011) noted maximum RGR and NAR when green gram was sprayed with 50 ppm NAA + cow urine. Medhi *et al.* (2014) observed that application of 60 kg P_2O_5 ha^{-1} + NAA @ 100 ppm significantly improved LAI, RGR, NAR and SLW at different stages of growth in green gram.

Bhosle *et al.* (2007) reported higher SLW in blackgram with the foliar application of 20 ppm NAA at flowering stage. Kalyankar *et al.* (2008) showed that foliar spray of NAA (100 ppm) was effective in increasing total dry weight of soybean. Shohag *et al.* (2008) observed improved growth and yield with spray of

200 ppm NAA in mung bean. Jeyakumar *et al*. (2008) reported that LAI and LAD were positively influenced by application NAA at 40 ppm by recording 2.84 and 19.3 days respectively in blackgram.

Ramesh and Ramprasad (2013) found that morpho-physiological parameters, *viz.,* plant height, number of branches, number of trifoliate per plant, dry matter accumulation in leaf, stem and reproductive parts, LAI, CGR and RGR were observed to increase significantly with the application of NAA (20 ppm) in soybean. Kapase *et al*. (2014) reported that foliar spray of 50 ppm NAA+400 ppm humic acid significantly enhanced RGR and NAR, in chickpea. Rajesh *et al.* (2014) found that application of NAA (20 ppm) during reproductive stage recorded higher chlorophyll content and photosynthetic rate in green gram. Upadhyay and Ranjan (2015) recorded significantly higher values of RGR, CGR and NAR in spray application of NAA 20 ppm in chickpea. Kashyap *et al.* (2018) observed that application of NAA 40 ppm+zinc 300 ppm produced superior LAI, LAD, CGR, RGR, SLW and chlorophyll content in green gram.

2.3.1.3 Effect on Yield Attributes and Yield

Ramesh *et al.* (2001) noticed increase in seed yields by 5.3 per cent with the application of 2 sprays of 20 ppm NAA to soybean at flowering and early pod formation stage. Increase in the dry matter accumulation in stem and reproductive parts, pod number, number of grains per plant and grain yield with the application of NAA was noticed by Araújo *et al.* (2021). However, 100 seed weight remained unaffected.

Subbian and Chamy (1984) remarked that foliar spray with NAA (10 ppm) twice at the time of flowering and 15 days thereafter increased the pod number per plant and seed yield per plant over control in greengram. Spraying NAA at flower initiation and seed filling stages also increased the seed yield in greengram and blackgram (Chaplot *et al.,* 1992). Setia *et al.* (1993) reported that foliar application of NAA 50 and 100 µ g mL^{-1} to lentil caused increase in seed yield, total dry matter and harvest index. Baghel and Yadava (1994) found higher seed yield in blackgram due to the application of 30 ppm NAA.

Kalita *et al.* (1995) recorded the highest seed yield and harvest index in summer and *Rabi* green gram sprayed with a combination of 3.0 per cent P_2O_5 + 100 ppm NAA. Lakshmamma and Rao (1996a) observed that foliar application of NAA twice at 50 per cent flowering and one week later decreased flower drop in blackgram in shaded condition.

Patel and Saxena (1994) and Lakshmamma and Rao (1996a) reported increased dry matter production due to the application of NAA in blackgram. Mahla *et al*. (1999) noticed highest dry matter production with 20 ppm NAA spray in blackgram.

Application of NAA at 40 ppm was more effective and significantly increased the number of seeds per plant, number of pods per plant, pod weight, pod dry weight, pod length and grain yield in blackgram. The increase in yield by the application of NAA might be attributed to its unique role in delaying senescence process, hastening root and shoot growth, higher fertility rate of reproductive organ due to creation of favorable balance of hormones and setting more fruits (Prabhu, 2000).

Kothule *et al.* (2003) and Chandrasekhar and Bangarusamy (2003) recorded the highest number of pods per plant and yield when sprayed with NAA 40 ppm at flowering stage compared to control (without NAA spray) in green gram and soybean respectively. Prakash *et al.* (2003) reported that combined application of NAA at 30 ppm on 30 and 45 DAS and mepiquat chloride at 120 ppm on 60 DAS recorded increased yield by 25 per cent more than the control.

Das and Prasad (2003) observed that two sprays of NAA at 20 or 40 ppm significantly increased days to 50 per cent flowering, number of pods per plant, pod length, grains per pod and 1000 grain weight and grain and straw yields in summer mungbean. The increase in pod length with the application of NAA might be due to rapid cell division and increased elongation of individual cell. Growth regulators *viz.*, NAA, 2, 4 D and CCC have recorded higher seed yield, pod length, pod number and weight in cowpea. The increase in yield attributes might be due to supplementation of nutrients at the critical stage without physiological stress. Foliar application of nutrients enhanced the number of floral buds, prevented the floral shedding by maintaining optimum bio-physiological conditions in plants. Adequate and continuous nutrient availability through soil and foliar nutrition promotes the supply of assimilates to sink or yield container, thus enlarging the size of the yield structure (Resmi and Gopalkrishnan , 2004).

Patil *et al.* (2005) found that spraying of NAA significantly improved the seed yield by 21-22 per cent than the control through increased flower production (18%), clusters per plant (24%), pod setting percentage (31%) and pods per plant (55%). Resmi and Gopalkrishnan (2004) reported that NAA (15, 30 or 45 ppm) increased seed yield, pod length, pod weight, pod number per plant and pod number per unit area of cowpea plants. The impact of the foliar nutrients to meet the nutrient demand of the crop at the critical stage on site, where they are needed without stress, would have resulted in better growth and development of the crop and ultimately the yield attributing characters and yield.

The combination of 60 kg P_2O_5 ha^{-1} + 100 ppm NAA recorded the highest seed yield and harvest index (1.49 t ha^{-1} and 31.21%, respectively), which was associated with high number of pods per plant, branching pattern, 1000 seed weight and seeds per pod. The balanced growth habit, which induced more flower and fruiting body production with timely supply of nutrients through foliar spray might have reduced shedding of flowers and fruits, which led to a positive source - sink gradient of photosynthates translocation due to growth regulator (Medhi *et al.*, 2014).

Dixit and Elamathy (2007) reported that foliar application of DAP 2 per cent + NAA 40 ppm + B (0.2%) + Mo (0.05%) at 30 DAS significantly increased the dry weight of plants, number of pods per plant, seeds per pod, test weight, grain yield and haulm yield over the control in green gram. Aucharamal *et al.* (2007) observed significantly higher total dry matter accumulation per plant in blackgram compared in spraying of 40 ppm NAA at flower initiation and 15 days later. According to Behera and Elamathi (2007), 2 per cent foliar spray of DAP and NAA 40 ppm twice at 25 and 35 DAS significantly increased the number of pods per plant, number of seeds per pod, test weight, number of flowers, fertility coefficient, grain yield and haulm yield in green gram. This might be due to enhanced level of nutrient available in the rhizo-ecosystem of the foliar applied nutrients resulting in better plant growth and development. Application of nutrients would have resulted in better vegetative growth as observed by taller plants, more branches and efficient nodulation. This favourable influence of foliar application of nutrients could be ascribed to more and quick access to nutrients by plants at seedling and early development stages.

Kalyankar *et al.* (2008) found the highest biological yield in soybean with the foliar application of 50 ppm NAA (48.59 kg ha^{-1}). Kadam *et al.* (2008) studied the effect of NAA (30 ppm) and found that NAA is effective in increasing the number of pods per plant, number of grains per pod, dry matter and grain yield. The increase in grain and straw yields with enhanced nutrient application could be ascribed to increase in the activity of cytokinin in plant which leads to the increased cell division and elongation thereby results in better plant growth, drymatter production and higher photosynthesis (Prasad *et al.,* 2016).

Girisha (2010) observed that application of NAA at 20 ppm resulted in significantly higher seed yield (4.59 g per plant) in blackgram. According to Rhodes and Ashworth (1952), the metabolism of NAA (auxin derivative) generates the energy-rich phosphate and precursors of metabolic processes, which may be the factors in the initiation of enhanced growth processes. The increased growth and delayed senescence in turn, favoured increase in yield as most of the assimilates were translocated from the source to the sink under a stimulated environment. Limbikai (2012) reported that foliar spray of 2 per cent DAP + 40 ppm NAA at 45 and 55 DAS recorded significantly higher seed yield

(1202 kg ha^{-1}). Doss *et al.* (2013) recorded maximum grain yield with the foliar application of 1 per cent K + 200 ppm NAA on blackgram. This increase in yield could be associated with photosynthetic efficiency and translocation of photosynthates. This was attributed to mobilization of food materials to reproductive sink for perfect seed filling process by increasing hydrolyzing and oxidative enzyme activities.

Shashikumar *et al*. (2013) recorded foliar spray of 40 ppm NAA + 0.5 per cent chelated micronutrient + 2 per cent DAP given at 35 and 50 DAS recorded significantly higher total dry matter production (15.98 g per plant) and grain yield (1298 kg ha^{-1}) in blackgram. Application of NAA at 20 ppm at flower initiation recorded the highest number of pods per plant, seeds per pod and seed yield in soybean (Ramesh *et al*., 2001). Kapase *et al*. (2014) found that foliar sprays of 50 ppm NAA+400 ppm humic acid significantly enhanced number of pods per plant, 100 seed weight and seed yield ha^{-1} in chickpea.

Kashyap (2018) observed that foliar application of NAA (40 ppm) reduced flower drop in green gram and foliar application of applied NAA 40 ppm + zinc 300 ppm produced the maximum yield (1.44 t ha^{-1}).

2.3.1.4 Effect on Quality Characters

Upadhyay *et al*. (1993) reported an increase in protein content in chickpea with the application of NAA (100 ppm). According to Reddy and Shah (1984), the application of 50 ppm NAA did not influence the seed protein content significantly in groundnut. However, Ravikumar and Kulkarni (1988) opined that, NAA had no effect on protein and oil contents in soybean seeds. Application of 50 ppm NAA + 6 per cent cow urine at 25, 40 and 55 DAS, registered higher seed protein content (Ingale, 2007).

Ramesh and Ramprasad (2013) noted significant increase in the seed protein content with the application of NAA (20 ppm) on soybean. Kashyap *et al.*

(2016) recorded maximum protein content in green gram with NAA 40 ppm + zinc 300 ppm.

Senthil *et al.* (2003) reported that application of NAA (50 ppm) recorded significantly higher soluble protein content than control in soybean. Esther and Gautam (2020) observed higher higher protein content (31.50%) in blackgram variety T9 with combination of recommended dose of fertilizers (25:50:25kg NPK ha^{-1}), urea (2%) and NAA at 40 ppm.

2.3.1.5 Effect on Soil Physico-chemical Properties

Shashikumar *et al.* (2013) observed significantly higher available N and P content of soil (278.13 and 28.55 kg ha^{-1} respectively) with the application of RDF + foliar spray of 40 ppm NAA + 0.5 per cent chelated micronutrient + 2 per cent DAP in blackgram.

2.3.1.6 Effect on Nutrient Uptake

Shashikumar *et al.* (2013) reported that application of RDF + foliar spray of 40 ppm NAA + 0.5 per cent chelated micronutrient + 2 per cent DAP resulted in higher P and K uptake (88.32, 10.72 and 35.09 kg ha^{-1} respectively) in blackgram.

2.3.2 Effect of Salicylic Acid

Salicylic acid (SA) naturally occurs in plants in very low amounts and participates in the regulation of physiological processes such as stomatal closure, nutrient uptake, protein synthesis and inhibition of ethylene biosynthesis and transpiration (Shakirova *et al.*, 2003). Huang *et al*. (2008) studied salicylic acid and mentioned its role in plant signaling, growth and development. Salicylic acid contains GA and IAA which promotes cell replication. Salicylic acid (from Latin salix, willow tree, from the bark of which the substance used to be obtained) is a monohydroxybenzoic acid, a type of phenolic acid and a beta hydroxy acid. This colourless crystalline organic acid functions as a plant hormone. It is derived from the metabolism of salicin.

2.3.2.1 Effect on Growth Characters

Sujatha (2001) found that foliar application of salicylic acid (100 ppm) on green gram at 75 DAS increased the plant height (50.4 cm), root length (16.9 cm) and number of leaves (18.4 cm). Kothule *et al*. (2003) reported that plant growth substances of different concentrations *i.e.,* NAA and salicylic acid each at 100 and 200 ppm and urea at 1 and 2 per cent when applied exogenously as foliar spray improved morphological characters *viz*., plant height, number of branches, leaf area, total dry matter of plant and reduced the number of days to 50 per cent flowering in soybean.

Increased dry matter production (21.6 g per plant) in blackgram was recorded by the application of salicyclic acid (125 ppm) by Jeyakumar *et al.* (2008). Afshari *et al.* (2013) observed the highest leaf area with the application of salicylic acid in blackgram.

Ali and Mahmoud (2013) showed that foliar application of salicylic acid 500 ppm significantly enhanced plant height and number of branches per plant as compared with control in mung bean.

Kumar *et al*. (2018) reported that significantly higher number of branches was observed with the foliar application of 150 ppm salicylic acid at 40 DAS, 55 DAS and maturity in blackgram. Similarly increased number of branches in blackgram in foliar spray of salicylic acid 150 ppm at 40, 55 DAS was observed by Manjri *et al.* (2018).

2.3.2.2 Effect on Physiological Characters

Sujatha (2001) found that foliar application of salicylic acid (100 ppm) at 75 DAS increased LAI (21.30) in green gram. Sivakumar *et al*. (2001) observed enhanced soluble protein content and the nitrate reductase activity with application of salicylic acid (100 ppm).

Maity and Bera (2009) reported that foliar application of salicylic acid influenced different physiological and biochemical aspects of green gram by increasing assimilation rate which revealed increase in chlorophyll content and hill reaction activity in the leaf. Enhanced photosynthetic rate, stomatal conductance and transpiration rate with foliar application of salicylic acid was reported in soybean by Khan *et al*. (2010). Amutha *et al*. (2012) found that foliar spray of nutrients mixture with salicylic acid 100 ppm at 20, 30 and 40 DAS recorded higher LAI, LAD and SLW in urd bean.

Afshari *et al*. (2013) observed the highest values for net photosynthesis rate, transpiration rate and proline concentration with the application of salicylic acid in blackgram. Esther and Gautam (2020) observed the highest RGR (0.091 g g^{-1} day^{-1}) at 45-60 DAS due to the foliar application of urea + salicyclic acid at 50 ppm.

2.3.2.3 Effect on Yield Attributes and Yield

According to Singh *et al*. (1980), foliar spray of salicylic acid (5 ppm) increased the number of pods per plant, number of grains per pod and finally seed yield in Bengal gram. Singh and Kaur (1980) observed higher seed yield in green gram due to the application of salicylic acid (10 ppm). Kumar *et al*. (1999) reported that application of salicylic acid (50 ppm) showed significant increase in pod weight, number of pods per plant and grain yield in soybean. Sujatha (2001) reported that foliar application of salicylic acid (100 ppm) on green gram at 75 DAS increased number of pods per plant, number of seeds per pod, seed weight per plant, 100 seed weight and grain yield.

Kothule *et al*. (2003) found that foliar application of NAA and salicylic acid each (100 and 200 ppm) and urea (1% and 2%) reduced the number of days to 50 per cent flowering in soybean. Chandrasekhar and Bangarusamy (2003) observed that the combination of salicylic acid (100 ppm), DAP (2%), KCl (1%) and NAA (40 ppm) had influenced the total dry matter production and increased grain yield in mung bean. Similarly, Radhamani *et al*. (2003) reported higher dry matter accumulation with salicylic acid spray (100 ppm) in green gram.

Reddy *et al*. (2003) found increased seed yield with the foliar application of salicylic acid on ground nut. Enhanced seed yield was observed by Mandavia *et al*. (2006) in chickpea when salicylic acid applied was as foliar spray. Murtaza *et al*. (2007) noted enhanced yield and yield components in pea plant treated with salicylic acid. Jeyakumar *et al.* (2008) reported that the application of salicylic acid (125 ppm) as foliar spray enhanced the total dry matter production and seed yield in blackgram. Patel and Hemantaranjan (2012) found that the seed yield was increased by the application of salicylic acid in chickpea.

Amutha *et al*. (2012) recorded significantly higher total dry matter accumulation and seed yield of urd bean with foliar spray of nutrient mixture with salicylic acid (100 ppm) at 20, 30 and 40 DAS. TNAU (2012) advocate foliar spray of NAA (40 mg L^{-1}) and salicylic acid (100 mg L^{-1}) once at pre-flowering and another at 15 days later to increase flower production and pod setting in blackgram.

Ali and Mahmoud (2013) showed that foliar application of salicylic acid 500 ppm significantly increased number of pods per plant, number of seeds per pod, 1000 seed weight, seed weight per plant and seed yield per hectare in mung bean. Marimuthu and Surendran, (2015) found that application of MAP, DAP, brassionolide (0, 25 ppm), SA (100 ppm) and nutrient mixture increased the number of pods, yield of blackgram and BC ratio.

Manjri *et al*. (2018) observed that foliar spray of salicylic acid 150 ppm at 40, 55 DAS recorded maximum seed yield in blackgram. Kumar and Simainya (2019) reported the highest number of pods per plant with the application of salicylic acid 100 ppm at flowering in blackgram.

2.3.2.4 Effect on Quality Characters

Sujatha (2001) revealed that foliar application of salicylic acid (100 ppm) on green gram at 75 DAS increased seed protein (23.98%) and soluble protein (12.9%). Mandavia *et al*. (2006) found the protein content was increased with salicylic acid treatment (50 ppm and 100 ppm). Jeykumar *et al.* (2008) reported that the highest seed protein content in blackgram was recorded (24.5%) by foliar application of salicyclic acid (125 ppm).

2.3.2.5 Effect on Nutrient Uptake

Combined application of DAP (2%) + salicylic acid (100 ppm) + 0.05% sodium molybdate increased the nutrient N, P and K uptake in green gram (Kuttimani and Velayutham, 2011).

The above reviewed literature reveals the scope of intercropping in coconut garden and the effect of foliar nutrition and PGR on enhancing yield. However, the research work pertaining to the identification of blackgram varieties tolerant to shade is limited. Also, blackgram being a source limited crop with reduced sink activity, the role of nutrients and PGRs in enhancing the yield need to be investigated. Hence the present study on identification of shade tolerant varieties and effect of foliar nutrition and PGRs in enhancing productivity of blackgram in coconut garden was undertaken.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled ‘Productivity enhancement of blackgram (*Vigna mungo* (L.) Hepper) intercropped in coconut gardens’ was carried out at College of Agriculture, Vellayani during 2018-2021. The research programme aimed at identifying shade tolerant blackgram varieties suitable for coconut gardens, studying the effect of foliar nutrition and plant growth regulators on growth and yield of blackgram intercropped in coconut garden and working out the economics of cultivation. The materials used and the methods adopted for the study are detailed in this chapter.

3.1 DETAILS OF EXPERIMENT

3.1.1 Experimental Site

The field experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani, Kerala, India. It is located at 8^{o}25’57” N latitude and 76^{o}5’6” E longitude and at an altitude of 29 m above mean sea level.

3.1.2 Climate

The experiment was conducted during three seasons, *viz., Rabi* 2019-20 (October to January), summer 2020 (February - May) and *Rabi* 2020-21 (October to January). The standard weekwise data on weather parameters *viz.,* temperature, relative humidity and rainfall during the cropping season, collected from Department of Agricultural Meteorology, College of Agriculture, Vellayani, are presented in Appendix I, II and III and graphically represented in Fig. 1a and 3b.

3.1.3 Soil

The composite soil samples drawn from a depth of 0-15 cm soil was used for analyzing the mechanical composition and chemical properties before conducting the experiment and the data is furnished in Table 1. Soil of the experimental site was sandy clay loam in texture, belonging to the order Oxisols under Vellayani series.

3.1.4 Cropping History of the Experimental Site

The experimental field was previously under fallow for two months after the harvest of baby corn and amaranthus.

3.1.5 Cropping Season

The field experiments were conducted during three seasons with experiment I during *Rabi* 2019-20 (October to January) and experiment II during Summer 2020 (February - May) and *Rabi* 2020-21 (October to January).

3.2 MATERIALS

3.2.1 Crop and Varieties

Seeds of twelve promising blackgram varieties along with three cultures were used for the study. The seeds of varieties were collected from Tamil Nadu Agricultural University (TNAU), Coimbatore, University of Agricultural Sciences (UAS), Dharwad, Panjabrao Deshmukh Krishi Vidhyapeeth (PDKV), Akola and University of Agricultural Sciences (UAS) Bangalore. The important characteristics of the varieties are given in Table 2. The cultures used were Culture 4.5.8, 4.5.18 and 4.6.1. The Cultures 4.5.8 and 4.5.18 (both were parental cross of T9 x Rusami) and Culture 4.6.1 (parental cross of Sumanjana x T9) were developed at Kerala Agricultural University, College of Agriculture, Vellanikkara, Thrissur.

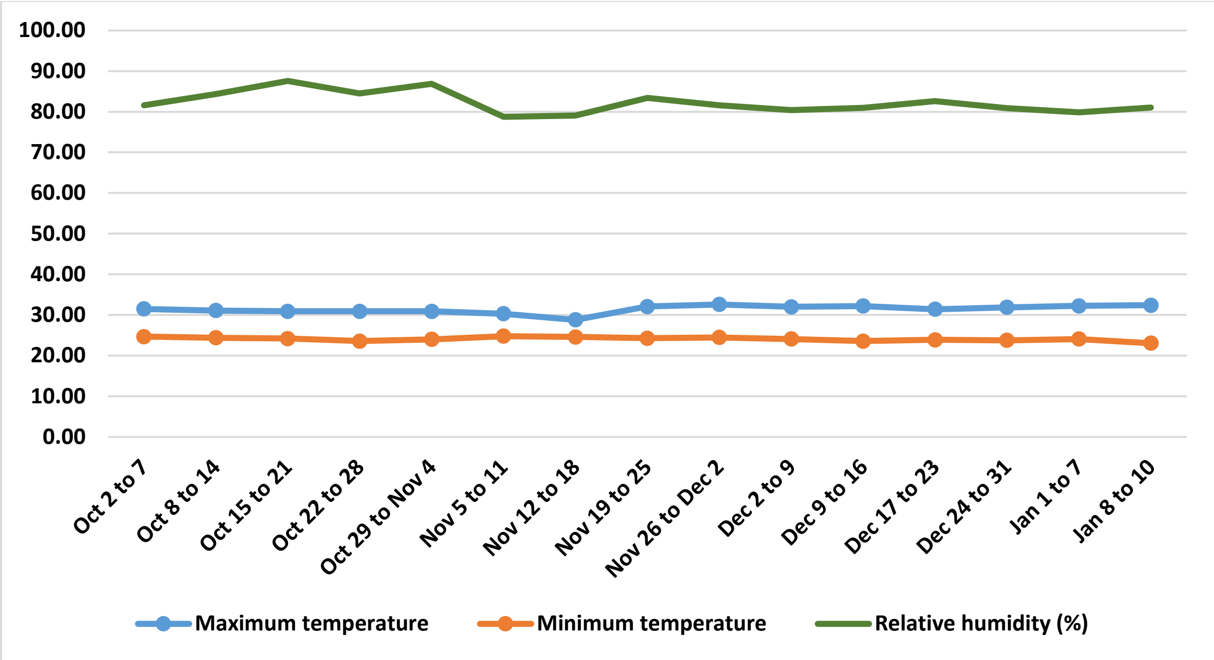

Fig. 1a Weather conditions during the cropping season (October 2019 - January 2020)

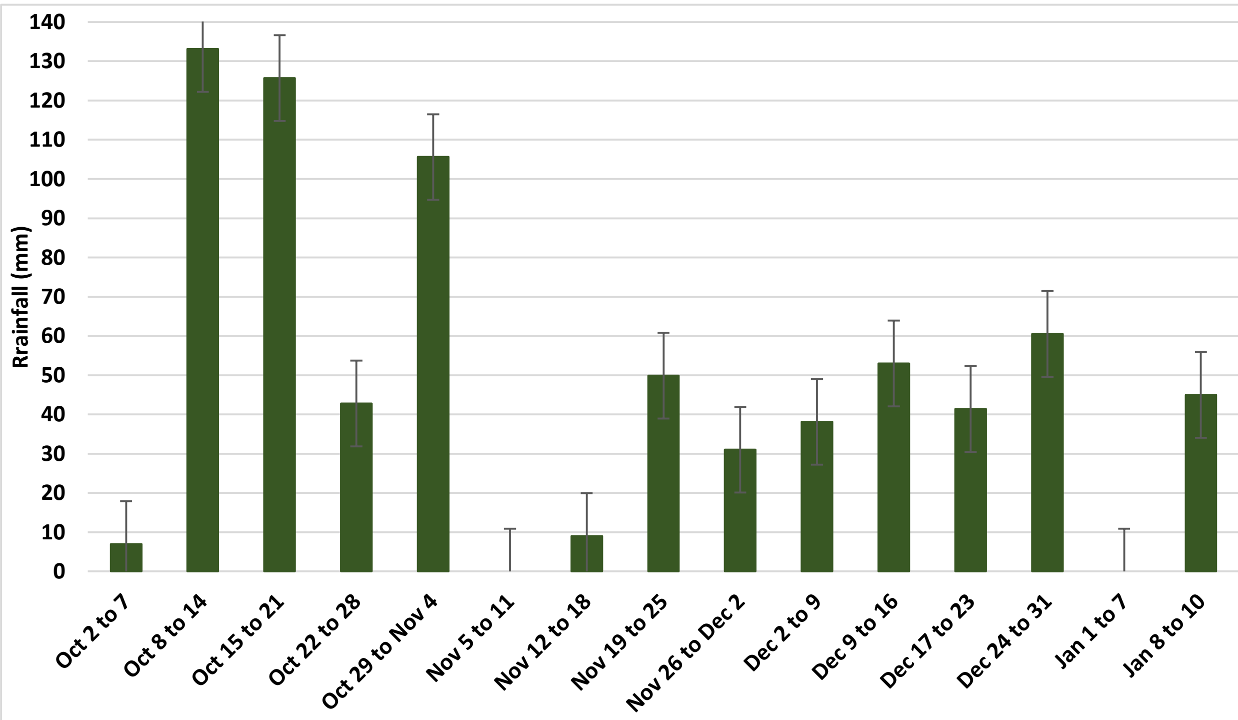

Fig. 1b Rainfall during the cropping season (October 2019 - January 2020)

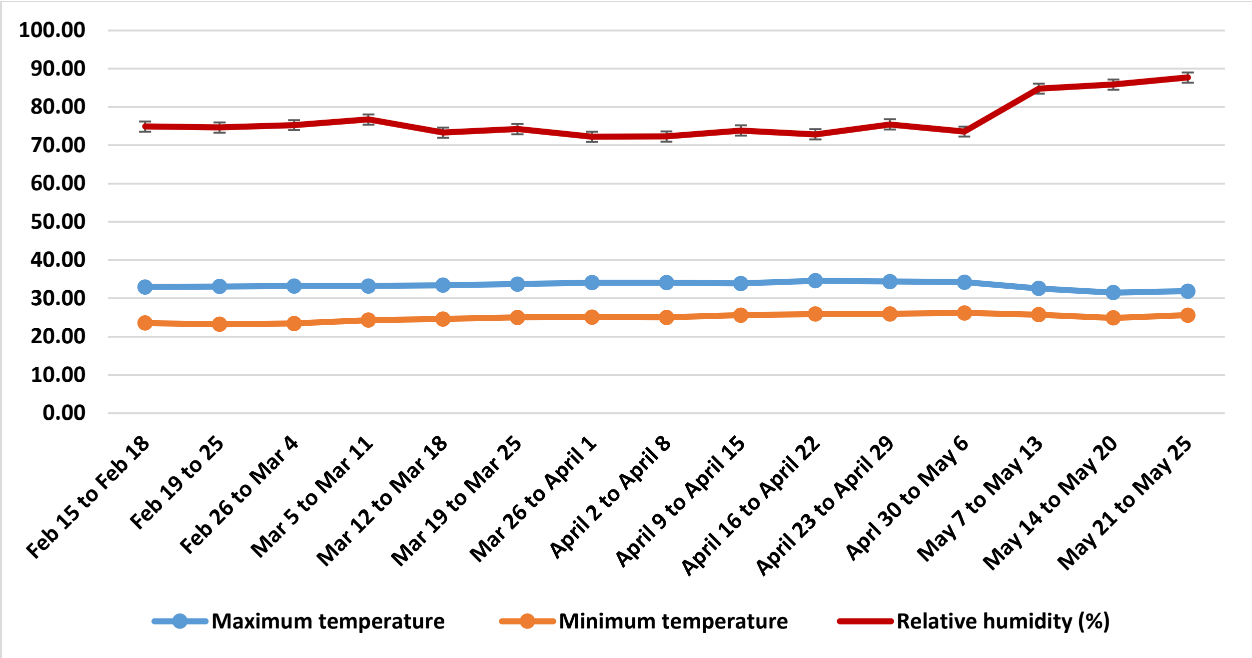

Fig. 2a Weather conditions during the cropping season (February 2020 –May 2020)

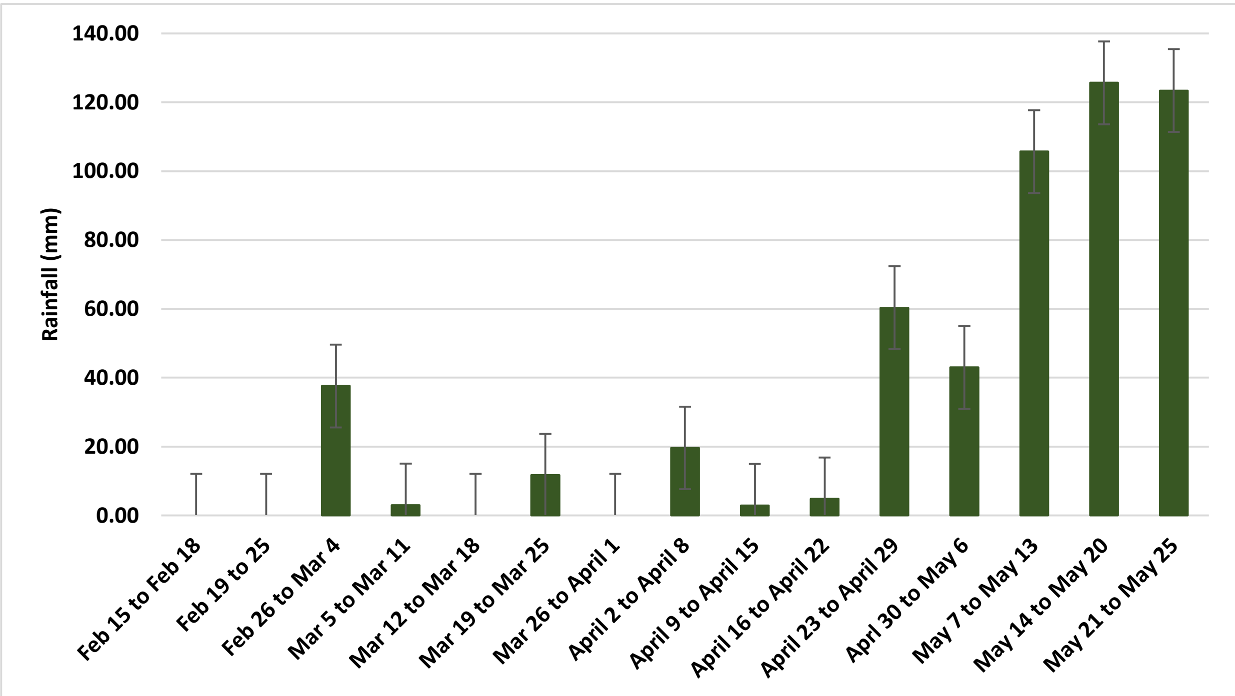

Fig. 2b Rainfall during the cropping season (February 2020 –May 2020)

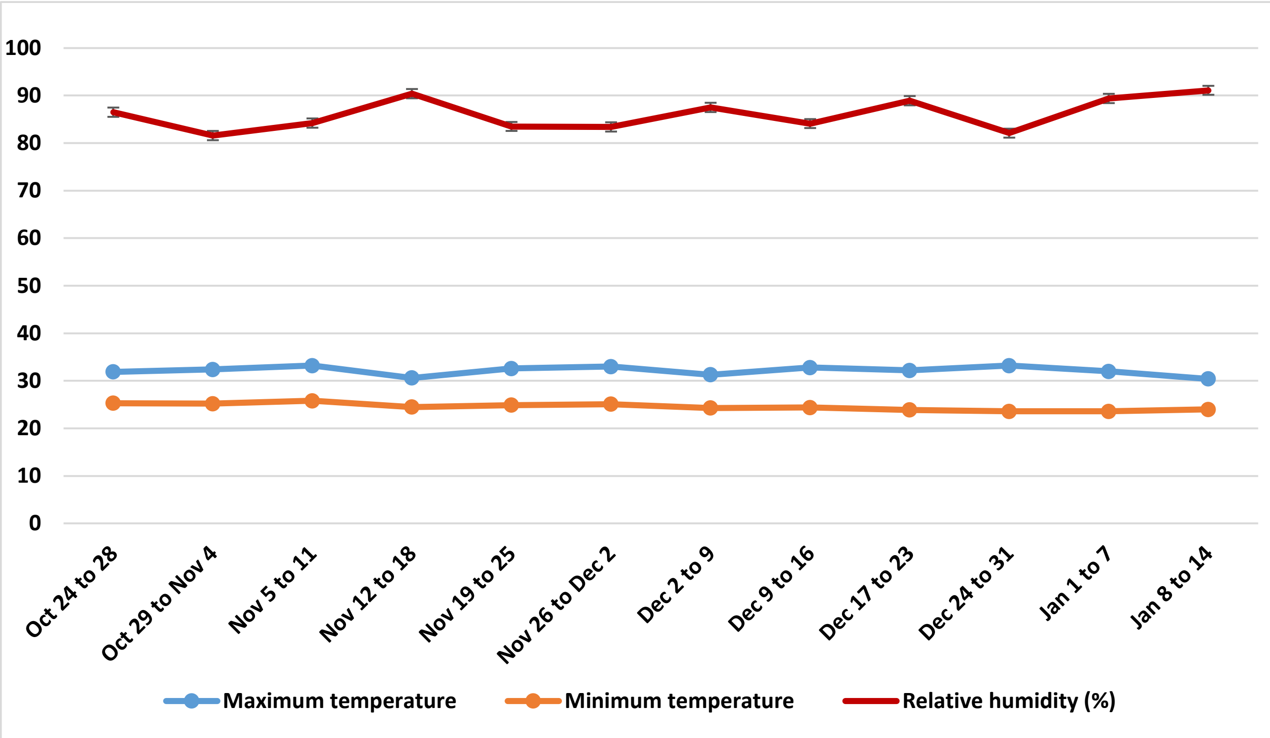

Fig. 3a Weather conditions during the cropping season (October 2020 - January 2021)

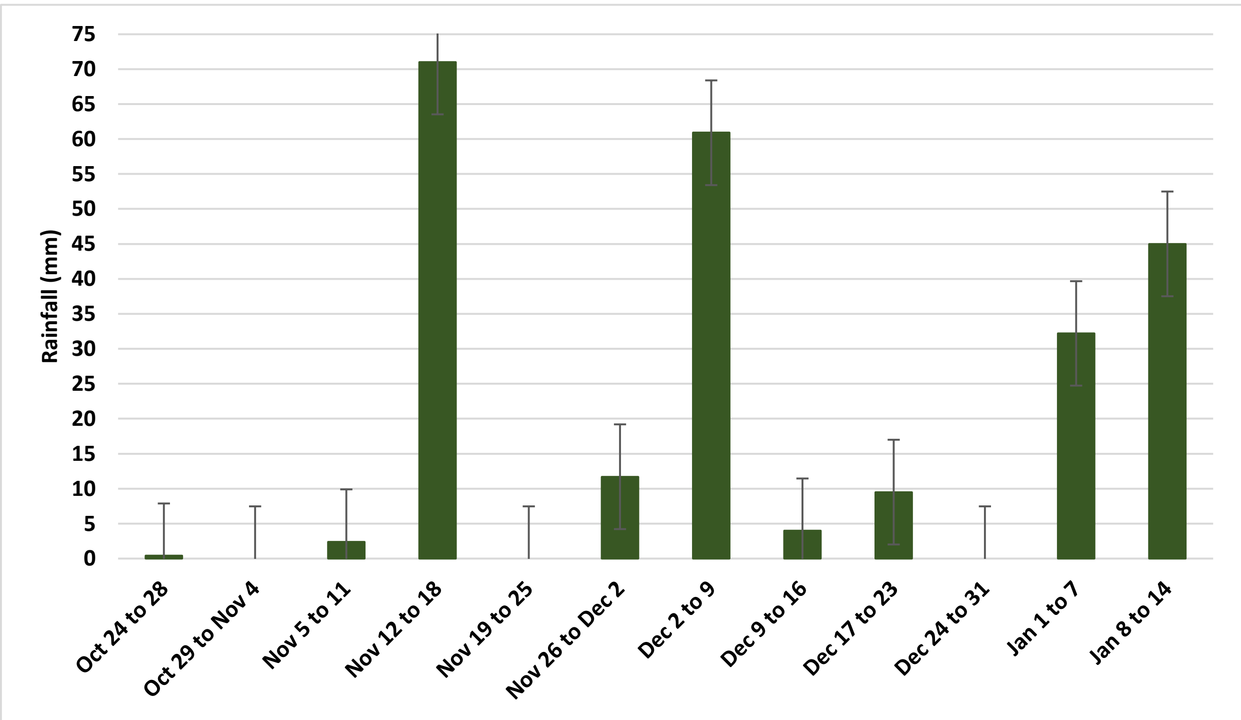

Fig. 3b Rainfall during the cropping season (October 2020 - January 2021)

Table 1. Physico - chemical properties of the soil in the experimental field

Characteristics		Content (%)	Method
Mechanical composition			
Coarse sand		16.70	International pipette method (Piper, 1966)
Fine sand		30.38	
Silt		25.50	
Clay		26.50	
Textural class		Sandy clay loam	
Particular	EXPT I	EXPT II	Reference
Soil reaction (pH)	6.1 (Slightly acidic)	5.9 (Moderately acidic)	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (dS m^{-1})	0.155 (Safe)	0.145 (Safe)	Digital conductivity meter (Jackson, 1973)
Organic carbon (%)	0.92 (high)	0.93 (high)	Walkley and Black Rapid Titration method (Jackson,1973)
Available N (kg ha^{-1})	188.16 (low)	191.30 (low)	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1}	31.25 (high)	33.21 (high)	Bray colorimetric method (Jackson, 1973)
Available K (kg ha^{-1})	340.14 (high)	345.24 (high)	Neutral normal ammonium acetate using flame photometer method (Jackson, 1973)

Table 2. Characteristics of blackgram varieties used for screening shade tolerance

Sl no.	Variety	Selection/Parentage	Year of release	Duration (Days)	Yield (kg ha^{-1})	Remarks	Seed source
1.	TAU 1	T 9 x UM 196	1985	65-70	1000-1200	Bold seed, fast growth	PDKV, Akola
2.	TAU 2	T 9 x U 196	1993	70	1000	Purplish black pods, seeds bold	PDKV, Akola
3.	Sumanjana	Pure line selection from Co Bg9	2000	75	933	Suited to summer rice fallows of Thiruvananthapuram	KAU
4.	AKU 15	TAU 1 x Pant U 31	2006	65-83	1000-1200	*Kharif*, tolerant to powdery mildew	PDKV, Akola
5.	VBN 5	CO 4 x PDU 102	2007	65-70	836	Hairy pods, 100 grain weight - 4 g, moderately resistant to yellow mosaic virus	NPRC, Vamban
6.	DU 1	TAU 1 x 169	2008	75-80	1000-1200	Suited to paddy fallows, tolerant to stem fly	UAS Dharwad
7.	CO 6	DU 2 x VB 20	2010	60-65	733	Moderately resistant to yellow mosaic virus	TNAU
8.	Rashmi	LBG 17 x UG 201	-	80-85	1000	Hairy pods, protein 20-25%	UAS, Bangalore
9.	VBN 6	VBN 1 x UK 17	2011	65-70	850	Hairy pods, synchronized pod maturity, moderately resistant to yellow mosaic virus	NPRC, Vamban
10	DBGV 5	TAU 1 x LBG 20	2012	82-85	1200	Moderately resistant to yellow mosaic virus	UAS Dharwad
11.	VBN 8	VBN 3 / VBN 04-008	2016	65-75	900	Non shattering, synchronous maturity, protein content - 21.9 %, arabinose content - 7.5%	NPRC, Vamban
12.	Blackgold	AKU- 10 -1	2016	70-75	1000-1100	Tolerant to powdery mildew	PDKV, Akola

Plate 1. Seeds of selected blackgram varieties and cultures

3.2.2 Rhizobium Culture

Rhizobium culture containing strain BMBS 47 suitable for inoculation of blackgram was procured from Tamil Nadu Agricultural University, Department of Agricultural Microbiology, Coimbatore.

3.2.3 Manures and Fertilizers

Dried cow dung powder with a nutrient content of 0.45, 0.17 and 0.50 per cent N, P_2O_5 and K_2O was used for the experiment. Urea (46% N), rajphos (20% P_2O_5) and muriate of potash (60% K_2O) respectively were used as the inorganic sources of N, P and K. Water soluble fertilizers, *viz*., 19:19:19 (NPK) and potassium sulphate (K_2SO_4) containing 50 per cent K_2O were used as nutrient sources for foliar treatments. Plant growth regulators *viz.,* naphthalene acetic acid ($C_{10}H_{12}O_2$ with molecular weight of 186.21g from TCI Chemicals Ltd.) and salicylic acid (99.5% AR grade from LOBA chemicals Ltd.) were used as sources of growth regulators for foliar application.

3.3 METHODS

3.3.1 Experiment I: Screening of Blackgram Varieties for Shade Tolerance (Micro Plot Study)

3.3.1.1 Experimental Design and Layout

Design : RBD

Treatments : 15

Replications : 3

Spacing : 25 cm x 15 cm

Plot size : 1.0 m x 0.9 m

Season : *Rabi* 2019-20

The field was laid out as per the design and micro plots of size 1.0 m x 0.9 m were taken. The layout of the field is given in Fig. 4.

3.3.1.2 Treatments

Treatments comprised of 12 blackgram varieties along with three cultures.

T_1- Sumanjana	T_6 - Culture 4.5.18	T_{11} - Rashmi
T_2 - DU 1	T_7 - VBN 6	T_{12} - CO 6
T_3 - DBGV 5	T_8 - VBN 8	T_{13} - Blackgold
T_4 - Culture 4.6.1	T_9 - VBN 5	T_{14} - TAU 1
T_5 - Culture 4.5.8	T_{10} - TAU 2	T_{15} - AKU 15

3.3.1.3 Shade Level Assessment

Coconut garden with palms of uniform age (45-50 years old), planted at a spacing of 7.6 m x 7.6 m was selected for screening. The shade level was assessed using light meter and light intensity of 56.25 klux equivalent to 50 per cent of that in open condition was recorded in the garden.

3.3.1.4 Field Preparation

The inter spaces of coconut palms were cleared by weeding and stubble removal, followed by cultivator ploughing and levelling using rotavator for easy seed bed preparation. From the base of the palm, two-meter radius was left to avoid interruption from coconut roots so that growth and development of intercrop was

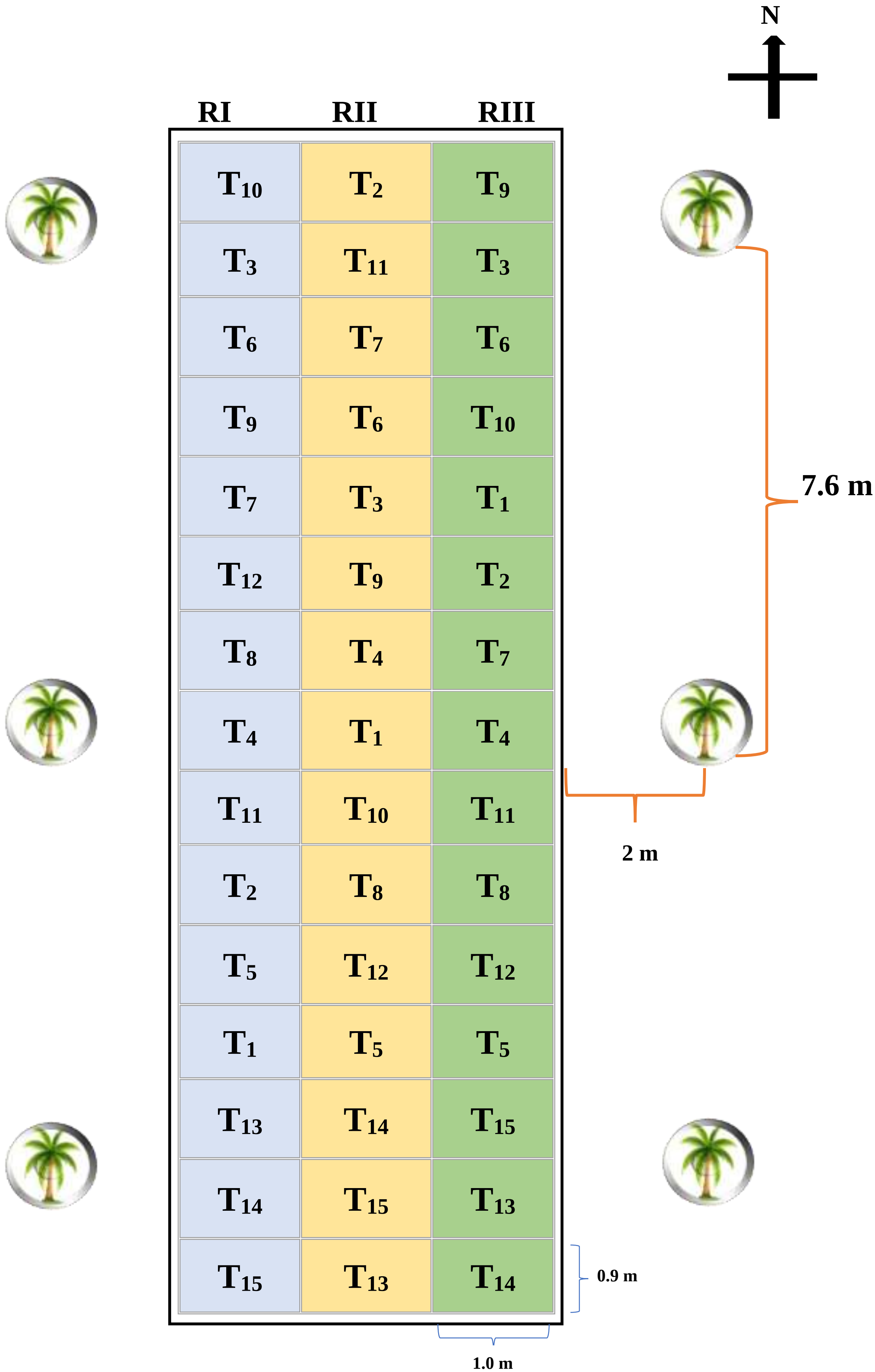

Fig. 4 Layout of experiment I (*Rabi* 2019-20)

Plate 2. Field view of the selected coconut garden

Plate 3. Layout of the experimental field (Experiment I)

unaffected. Hence in between two coconut palms, 3.6 m space was utilized for sowing. Micro plots of 0.9 m^2 were taken and lime @ 250 kg ha^{-1} incorporated in the soil.

3.3.1.5 Application of Manures and Fertilizers

Dried cow dung powder @ 20 t ha^{-1} was applied uniformly to all the plots and mixed well. A nutrient dose of 20: 30: 30 kg NPK ha^{-1} was adopted. Half the dose of N, full dose of P and K were applied as basal and the remaining N was applied as two foliar sprays of one per cent urea at 15 and 30 days after sowing (KAU, 2016).

3.3.1.6 Sowing of Seeds

The seeds of blackgram varieties were inoculated separately with *Rhizobium* culture BMBS 47 @ 250 g ha^{-1} and shade dried for 30 minutes. The seeds of each variety were sown on the beds at a spacing of 25 cm x 15 cm on 2nd October 2019 followed by irrigation.

3.3.1.7 Aftercultivation

Seed germination per cent was recorded from three days after sowing (DAS). The crop was thinned one week after emergence to maintain optimum plant population. Two weedings were done at 15 and 30 DAS respectively. Two irrigations were given, one immediately after sowing and another at flowering. At 20 DAS, three plants in each plot were randomly selected and tagged as observational plants. The general view of the experimental site and crop at various stages of growth are presented in Plate 4a to 4c.

3.3.1.8. Plant Protection

Tobacco caterpillar (*Spodoptera litura*) incidence noticed at 20 DAS was controlled using quinolphos 25 EC (KRUSH) @ 2 mL L^{-1} and the incidence of spotted pod borer (*Maruca vitrata*) at pod maturity stage was controlled using chlorantraniliprole 18.5 SC (CORAGEN®) @ 3 mL 10 L^{-1} and thiomethoxam (ACTARA 25% WG) @ 0.25 mL L^{-1}. Collar rot disease caused by *Rhizoctonia solani* was managed by spraying carbendazim (BAVISTIN 50 WP) @ 1g L^{-1}.

3.3.1.9 Harvest

Harvest of pods was completed with three pickings. One day prior to harvest, the observational plants were pulled out and the yield attributing characters and root characters were recorded. The crop duration ranged from 90-110 days among the varieties. The dry pods from individual net plot area were picked, sun dried and threshed separately to determine seed yield. The plant residues in the net plot area were uprooted, dried, and weighed to record haulm yield.

3.3.2 Experiment II: Performance Evaluation of Shade Tolerant Varieties under Foliar Application of Nutrients and Growth Regulators in Rainfed Coconut Garden

3.3.2.1 Experimental Design and Layout

The details of the field experiment are

Design	: Split-plot design
Treatments	: 30 (Main plot - 5; Subplot - 6)
Replications	: 4
Spacing	: 25 cm x 15 cm
Plot size	: 6 m x 3 m
Season	: Summer 2020 *Rabi* 2020-21

Plate 4a. Blackgram varieties and cultures at seedling stage (5 DAS)

Plate 4b Blackgram varieties and cultures at vegetative stage (1 MAS)

Plate 4c General view of the experimental field during *Rabi* 2019

3.3.2.2 Treatments

The treatments included five main plot treatments and six subplot treatments.

Main plot treatments -Varieties (V) - 5

The best performing five varieties from experiment I based on yield were selected for the conduct of experiment.

v_1 - Sumanjana

v_2 - DBGV 5

v_3 - VBN 5

v_4 - VBN 6

v_5 - CO 6

Subplot treatments - Foliar spray (F) - 6

f_1 - Foliar spray of 19:19:19 @ 1% at 45 and 60 DAS

f_2 -Foliar spray of SOP @ 0.5% at 45 and 60 DAS

f_3- NAA 40 mg L^{-1} and salicylic acid 100 mg L^{-1} at pre-flowering (30-45 DAS) and 15 days later

f_4 - $f_1 + f_3$

f_5 - $f_2 + f_3$

f_6 - Control (KAU POP)

* SOP - Sulphate of potash

* NAA - Naphthalene acetic acid

Control (KAU POP) : NPK @ 20: 30: 30 kg NPK ha^{-1} with half N, full P and K applied as basal in soil and remaining N as two foliar sprays of one per cent urea at 15 and 30 days after sowing

Treatment combinations: 30

v_1f_1	v_2f_1	v_3f_1	v_4f_1	v_5f_1
v_1f_2	v_2f_2	v_3f_2	v_4f_2	v_5f_2
v_1f_3	v_2f_3	v_3f_3	v_4f_3	v_5f_3
v_1f_4	v_2f_4	v_3f_4	v_4f_4	v_5f_4
v_1f_5	v_2f_5	v_3f_5	v_4f_5	v_5f_5
v_1f_6	v_2f_6	v_3f_6	v_4f_6	v_5f_6

3.3.2.3 Details of Cultivation

The coconut garden selected for the initial screening of varieties was cleared and used for raising the crop in the second experiment.

3.3.2.4 Field Preparation

The field was ploughed twice using cultivator and the plots were levelled using rotavator, for easy bed preparation. Lime @ 250 kg ha^{-1} was applied uniformly to the soil and mixed well, followed by light irrigation. A radius of two metres was left from the base of each coconut palm and beds of size 6 m length and 3 m width were taken as main plots in the interspace between coconut palms. The main plot was later divided into subplots of size 3 m x 1 m. The field layout is given in Fig. 5.

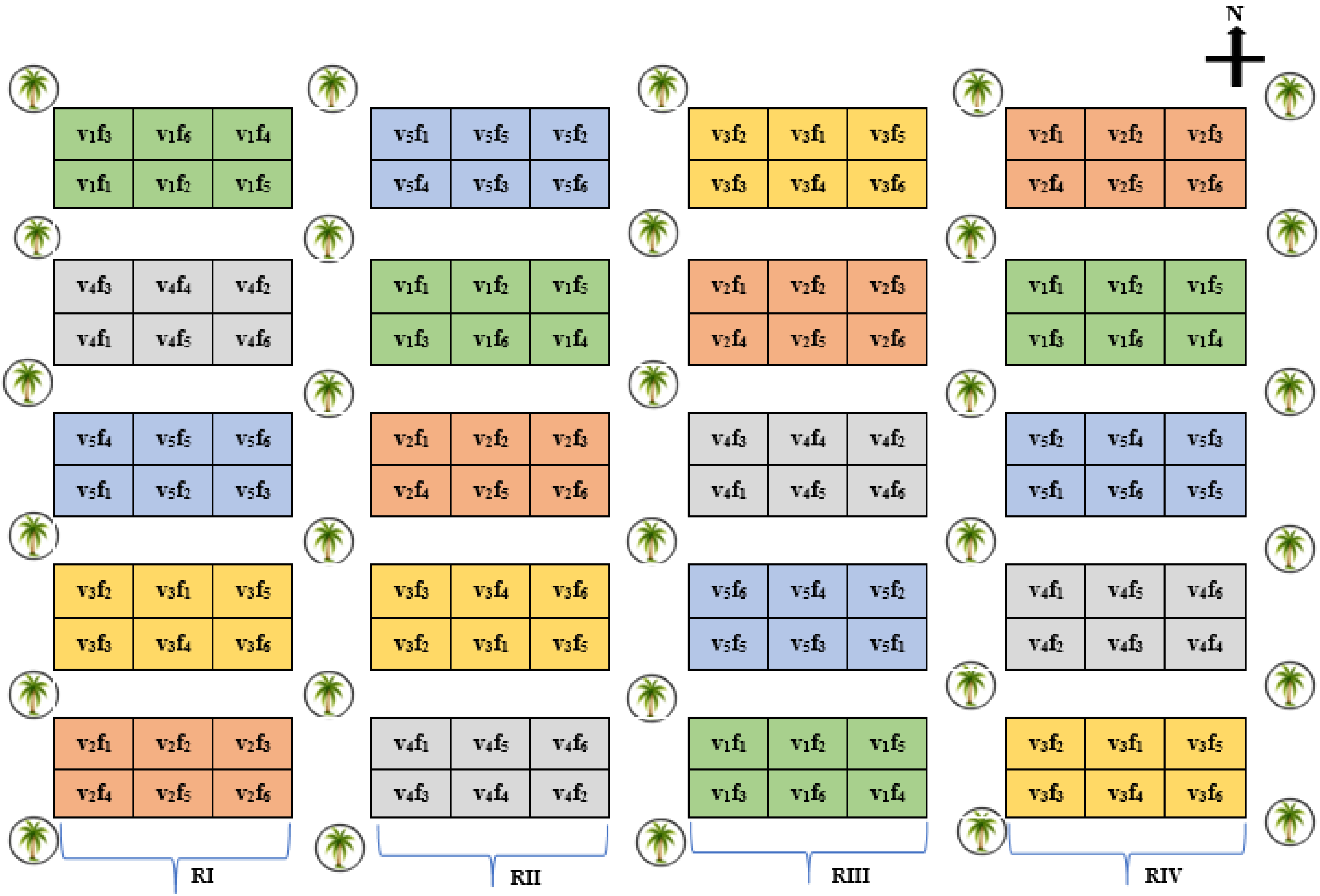

Fig. 5 Layout of experiment II (summer 2020 and *Rabi* 2020-21)

Plate 5a Layout of the experimental field (Experiment II)

Plate 5b Rhizobium treatment and sowing of blackgram varieties (Experiment II)

Plate 6a General view of the experimental field during summer 2020

Plate 6b General view of the experimental field during *Rabi* 2020-21

3.3.2.5 Application of Manures and Fertilizers

Dried cowdung powder @ 20 t ha^{-1} was applied uniformly, mixed well and a nutrient dose of 20: 30: 30 kg NPK ha^{-1}. Half the dose of N, full dose of P and K were given as basal and remaining N was applied as two foliar sprays in the form of urea (2%) at 15 DAS and 30 DAS (KAU, 2016). The foliar fertilizers, 19:19:19 and SOP and the plant growth regulators, NAA and SA were sprayed as per the treatments to the respective subplots at specified concentration.

3.3.2.6 Sowing of Seeds

The seeds of five varieties were separately inoculated with *Rhizobium* culture 250 g ha^{-1} and shade dried for 30 minutes. The varieties were sown on 15^{th} February 2020 during summer and 24^{th} October 2020 during *Rabi* in the respective main plots at a spacing of 25 cm x 15 cm. Light irrigation was provided after sowing.

3.3.2.7 Aftercultivation

Same as experiment I

3.3.2.8 Plant Protection

The incidence of powdery mildew was noticed at 20 DAS and was controlled by spraying carbendazim (BAVISTIN 50 WP) @ 1g L^{-1}. At pod maturity stage, incidence of spotted pod borer (*Maruca vitrata*) was noticed and controlled using chlorantraniliprole 18.5 SC (CORAGEN®) @ 3 mL 10 L^{-1}.

3.3.2.9 Harvest

Harvesting and separation of seeds were done as detailed in experiment I.

3.4 OBSERVATIONS

Leaving the single row of plants on the plot borders, three representative plants remaining diagonally in the same direction selected at random from each net plot were tagged as observational plants for recording biometric observations.

Experiment I

3.4.1 Growth Characters

Growth characters were recorded at monthly intervals from three observational plants and mean values worked out.

3.4.1.1 Plant Height

Plant height was taken from the base to the growing tip of the observational plants at monthly intervals and the average height at each stage was expressed in cm.

3.4.1.2 Number of Leaves per Plant

The mean values for the number of trifoliate leaves per plant were computed from the observational plants, at monthly intervals and recorded.

3.4.1.3 Number of Branches per Plant

Number of branches from observational plants were recorded and average number of branches per plant was worked out.

3.4.1.4 Leaf Area Index

Leaf area per plant was calculated at 50 per cent flowering using the length and breadth measurement method and expressed in cm^2.

$$\text{Leaf area} = L \times B \times K \times n$$

(a)Urea spray at 15 DAS

(b)Treatment application

(c) Measurement of stomatal conductance

Plate 7. Stages of field experimentation (Experiment II)

Plate 8. Harvest of the crop

where,

L = length of leaf (cm)

B = breadth of leaf (cm)

K (constant value) = 0.631 (Montgomery, 1911)

n = number of leaves

Using the calculated value of leaf area per plant, leaf area index (LAI) was computed with the formula,

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

3.4.1.5 Number of Nodules per Plant

The number of nodules per plant was counted at flowering stage. Two plants were uprooted from each net plot area and roots were washed thoroughly to remove dirt and soil particles. The nodules from each plant were removed and counted separately and average values recorded.

3.4.1.6 Dry Weight of Nodules per Plant at flowering

The nodules separated from each plant at flowering stage were oven dried at (65 ± 5)ºC to constant weight and the weight of nodules per plant was recorded and expressed in g.

3.4.2 Root Characters (At Harvest)

3.4.2.1 Rooting Length

At harvest, three plants at random were uprooted from each plot. The length of the root was measured after washing to remove soil particles and dirt. The average rooting length was calculated and expressed in cm.

3.4.2.2 Root Volume

Root volume was measured by water displacement method (Mishra and Ahmad, 1990). The roots of the observational plants washed with water and made free of adhering soil was immersed in a graduated cylinder containing water. Volume of the displaced water was taken as the volume of the root and its average was expressed in cm^3.

3.4.2.3 Root Dry weight

At harvest, three plants were uprooted from uniform soil depth in each plot at random. The roots of the plants were washed and made free of soil particles and dried in hot air oven at (65 ± 5) ºC to constant weight and expressed in g.

3.4.3 Physiological Characters (At Flowering)

3.4.3.1 Photosynthetic Rate

Photosynthetic rate was measured during the morning hours between 11 am and 1 pm using Portable Photosynthetic System (CIRAS-3, PP systems U.S.A) and the values were expressed in µ CO_2 moles m^{-2} s^{-1}.

3.4.3.2 Leaf Area Duration

Leaf area duration (LAD) is the measure of its ability to produce leaf area on unit area of land throughout its life. Using the values of leaf area, recorded at 30, 45 and 60 DAS, LAD was calculated with the equation proposed by Watson (1947) and expressed in days. The equation is:

$$\text{LAD} = \frac{(L_1 + L_2)}{2} (t_2 - t_1)$$

where, L_1 and L_2 are the leaf area index at the t_1 and t_2 time respectively.

3.4.3.3 Chlorophyll Content

The total chlorophyll content at flowering was estimated by the method suggested by Arnon (1949) in which, the fully opened second leaf from the top of plants were used and the values expressed in mg g^{-1} of fresh weight of leaf.

$$\text{Total chlorophyll} = \frac{8.02\ A_{663} + 20.20\ A_{645}\ \ x\ V}{1000\ x\ W}$$

where,

A: Absorbance at specific wavelengths

V: Final volume (mL) of chlorophyll extracted in 80 per cent acetone

W: Fresh weight (g) of tissue extracted in 80 per cent acetone

3.4.3.4. Stomatal Index

Stomatal index is the ratio of the number of stomata formed to the total number of epidermal cells, expressed in percentage where, each stoma being counted as one cell. It was computed at flowering using the following equation:

`

$$I = \frac{S}{E + S}\ x\ 100$$

where,
I: Stomatal index
S: No. of stomata per unit area
E: No. of epidermal cells in the same unit area

3.4.3.5 Proline Content

Proline content at flowering was estimated using the procedure described by Bates *et al.* (1973). A known amount (0.5 g) of mid-leaf portion, homogenized with

10 mL of 3 per cent aqueous sulphosalicylic acid was centrifuged at 3000 rpm for 15 minutes. Two mL of the supernatant, mixed with an equal amount of glacial acetic acid and acid ninhydrin were allowed to react at 100^0C for one hour in water bath. The reaction was terminated by keeping it in ice bath for 10 minutes and the reaction mixture was mixed with 4 mL toluene using vortex mixture for 15 - 20 seconds. The chromophore containing toluene, aspirated from aqueous phase and warmed to room temperature was utilised for reading the optical density at 520 nm with toluene as blank. A standard curve of concentration verses absorbance was drawn.

From the graph, the concentration of proline was determined and expressed as

$$\mu \text{ moles } g^{-1} \text{ tissue} = \frac{[\mu g \text{ proline } /mL \times mL \text{ toluene}] \times 5}{115.5 \times \text{weight of sample (g)}}$$

where, 115.5 is the molecular weight of proline.

3.4.4 Yield Parameters

3.4.4.1 Days to 50 Per Cent Flowering

The number of days taken by 50 per cent of plants to flower was recorded.

3.4.4.2 Number of Pods per Plant

Pods collected separately from the observational plants from each plot were counted and the mean worked out and recorded.

3.4.4.3 Number of Seeds per Pod

Pods used for measuring the pod length were threshed separately and the number of seeds in each pod was counted and the mean value worked out.

3.4.4.4 Average Length of Pod

Ten pods selected at random from the observational plants of each treatment were used for taking length measurements whose averages were worked out and expressed in cm.

3.4.4.5 Hundred Seed Weight

Weight of 100 bold fully filled blackgram seeds, selected from each net plot, were recorded and expressed in g.

3.4.4.6 Seed Yield per Plant

The observational plants of each variety were harvested, threshed and dried to a moisture content of 12 per cent. The seeds thus obtained were weighed and the average weight expressed as g per plant.

3.4.4.7 Haulm Yield per Plant

Seeds of the harvested observational plants were separated and the remaining plant portions were dried to record the haulm yield per plant as g per plant.

3.4.4.8 Seed Yield

After drying the seeds to a moisture content of 12 per cent, the seeds obtained from each net plot were weighed separately and expressed in kg ha^{-1}.

3.4.4.9 Haulm Yield

Seeds of the harvested plants from each net plot were separated and the remaining plant portions were dried under sun and weighed to record haulm yield in kg ha^{-1}.

3.4.4.10 Harvest Index

Harvest index was worked out on the basis of the economic (seed) and biological (haulm) yields from the net plot, using the formula suggested by Nichiporovich (1960).

$$HI = \frac{\text{Seed yield}}{(\text{Seed yield} + \text{Haulm yield})}$$

3.4.5 Dry Matter Partitioning at Harvest

3.4.5.1 Shoot Weight

From the dried sample of the whole plant, shoot weight was recorded and expressed in g per plant.

3.4.5.2 ***Root Weight***

From the dried sample of the whole plant, root weight was recorded and expressed in g per plant.

3.4.5.3 Leaf Weight

From the dried sample of the whole plant, leaves were separated for recording the leaf weight and values expressed in g per plant.

3.4.5.4 Pod Weight

From the dried whole plant sample, the pods were separated for recording pod weight and the values expressed in g per plant.

3.4.5.5 Seed Weight

Seeds obtained from the dried pods were used to record seed weight and values expressed in g per plant.

3.4.5.6 Total Dry Matter

Observational plants uprooted from each plot separated into different plant parts were sun dried and oven dried at $(65 \pm 5)^{0}$C for 48 hours to constant weight. The weight of different plant parts was added to obtain the total dry matter and expressed in g per plant.

3.4.6 Light Intensity (klux) and Photosynthetically Active Radiation (µ moles m^{-2} s^{-1})

The total light intensity was measured using light meter (Model LI – 250) according to the procedure suggested by Thavaprakash and Velayudham (2007). The photosynthetically active radiation (PAR) was measured using Quantum Sensor.

EXPERIMENT II

3.4.7 Growth Characters

Five observational plants from each subplot were tagged and growth characters *viz.*, plant height, number of leaves per plant, number of branches per plant at monthly intervals and leaf area index, number and dry weight of nodules per plant at flowering were recorded similar to Experiment I.

3.4.8 Root Characters

The root characters were recorded at harvest similar to Experiment I.

3.4.9 Light Intensity and Photosynthetically Active Radiation

The light intensity and PAR at monthly interval were measured using light meter and quantum sensor respectively.

3.4.10 Physiological Characters (30 DAS, 60 DAS and At Harvest)

3.4.10.1. Crop Growth Rate

Crop growth rate (CGR) refers to the overall increase in the dry weight of a crop plant per unit land area per unit time with the help of the formula suggested by Leopold and Kridemann (1975). It is expressed as g $m^{-2}day^{-1}$. To work out CGR, one plant each was uprooted at 30, 45, 60 and 75 DAS from uniform soil depth in each net plot and dried at (65 ± 5)ºC to a constant weight. CGR was worked out between 30-45, 45-60 and 60-75 DAS using the formula

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

where,

W_2 and W_1: Total dry weight of the plant at the time t_2 and t_1 respectively

P: Ground area

3.4.10.2 Relative Growth Rate

Relative growth rate (RGR) refers to the rate of increase in the dry weight of a crop plant in relation to its initial dry weight, calculated using the formula given by Williams (1946) and expressed as g g^{-1} day^{-1}. To work out RGR, one plant each was uprooted at 30, 45, 60 and 75 DAS from net plot at uniform soil depth and dried at (65 ± 5)ºC to reach a constant weight. RGR was worked out between 30-45, 45-60 and 60-75 DAS using the formula

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

where,

W_2 and W_1: Whole plant dry weight at times t_2 and t_1 respectively

t_2 - t_1: Time interval

3.4.10.3 Specific Leaf Weight

Specific leaf weight (SLW), calculated using the formula by Pearce *et al*. (1969) is a measure of leaf weight per unit leaf area, expressed in mg cm^{-2}. Length and breadth of leaf and total number of leaves of a plant at 30, 45, 60 and 75 DAS were recorded. Leaves were dried in an oven at (65 ± 5) ºC to constant weight and SLW was calculated using the formula

$$SLW = \frac{\text{Leaf dry weight per plant}}{\text{Leaf area per plant}}$$

3.4.10.4 Net Assimilation Rate

Net assimilation rate (NAR) denotes the rate of increase in total dry weight per unit leaf area per unit time. It was calculated based on the formula given by Williams (1946) and expressed in g cm^{-2} day^{-1}. One plant was pulled out from each net plot at a uniform depth at 30, 45, 60 and 75 DAS and observations on length, breadth and number of leaves were taken. Then plant was oven dried at (65 ± 5) ºC to constant weight and NAR was calculated using the formula

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log_e L_2 - \log_e L_1)}{(L_2 - L_1)}$$

where,

$\log_e L_2$: Natural log of leaf area at time t_2

$\log_e L_1$: Natural log of leaf area at time t_1

L_2 and L_1: Leaf area at times t_2 and t_1 respectively

W_2 and W_1: Plant dry weight at times t_2 and t_1 respectively

$t_2 - t_1$: Time interval

3.4.10.5 Chlorophyll Content

Chlorophyll content at flowering was measured and expressed in mg g^{-1} of fresh tissue.

3.4.10.6 Stomatal Index

Stomatal index at flowering was computed by counting the number of stomatal cells and epidermal cell and expressed it as per cent.

3.4.10.7 Stomatal Conductance

Stomatal conductance was measured at flowering during morning hours between 9 a.m. and 11 a.m. using Portable Photosynthetic System (CIRAS-3, PP systems U.S.A) and expressed in m moles m^{-2} s^{-1}.

3.4.10.8 Soluble Protein

Soluble protein content in the leaf at flowering was estimated using Folin-Ciocalteau reagent at 660 nm following the procedure of Lowry *et al.* (1950). Leaf sample weighing 250 mg was macerated with 10 mL of phosphate buffer and was centrifuged at 3000 rpm for 10 minutes. The supernatant was collected and made up to 25 mL using phosphate buffer. One mL of the supernatant was taken and 5 mL of alkaline copper tartarate reagent was added and was mixed with 0.5 mL of Folin-

Ciocalteau reagent. The OD value at 660 nm was measured in the spectrophotometer. The soluble protein content was expressed in mg g^{-1} fresh weight by using bovine serum albumin as the standard.

3.4.11 Yield Parameters: same as experiment I

3.4.11.1 Total Dry Matter Production (TDMP)

Seed yield and haulm yield obtained from each net plot area were sun dried and oven dried at (65±5) °C for 48 hours to a constant weight and expressed in kg ha^{-1}.

3.4.12 Quality parameters

3.4.12.1 Grain Dry Matter

After weighing, the seed was dried in an oven to constant weight and the dry matter was expressed in percentage.

3.4.12.2 Grain Protein

Grain protein content was calculated by multiplying nitrogen content with the factor 6.25 (Simpson *et al*., 1965) and expressed in percentage.

3.4.12.3 Nitrate (NO_3^-) Content

Nitrate content of the seed was estimated by the rapid colorimetric detection method and expressed as µg NO_3^- g^{-1} (Cataldo *et al.*, 1975).

3.4.13 Chemical Analysis

3.4.13.1 Soil Analysis

Soil samples were analysed both before and after the experiments to determine changes in pH, electrical conductivity, organic carbon and available NPK.

Standard procedure was followed for soil sample collection. The samples were sieved using a 2 mm sieve for pH, EC, available N, P and K estimation and, 0.5 mm sieve for organic carbon estimation. The analysis was done using standard procedure as shown in Table 1.

3.4.13.2 Plant Analysis

The observational plants, uprooted separately from each plot at the time of final harvest was air dried and then oven dried at $(65 \pm 5)^0$C to a constant weight. Later it was ground to a fine powder and used for analyzing the total N, P and K content.

3.4.13.2.1 Nitrogen Uptake

The total N content of shoot and seed was estimated by the Modified microkjeldahl method (Jackson, 1973). The N uptake was calculated by multiplying N content of shoot and seed with their TDMP and the sum was expressed in kg ha^{-1}.

3.4.13.2.2 Phosphorus Uptake

The total P content in the shoot and seed were estimated colorimetrically by the Vanadomolybdate phosphoric yellow colour method, after wet digestion. Intensity of the colour developed was read using spectrophotometer (Jackson, 1973). The total P uptake was then calculated by multiplying the P content of shoot and seed with their TDMP and the sum was expressed in kg ha^{-1}.

3.4.13.2.3 Potassium Uptake

The total K content in shoot and seed were estimated using Flame photometer (Jackson, 1973). The uptake was estimated by multiplying the K content of shoot and seed with their TDMP and the sum was expressed in kg ha^{-1}.

3.4.14 Incidence of Pest and Diseases

Pest and disease incidence noticed during the cropping period were recorded and scored on the basis of damage caused.

3.4.15 Economic Analysis

The economics of blackgram cultivation was worked out based on the cost of cultivation and prevailing market price of the produce.

3.4.15.1 Net Income

After computing the cost of cultivation and gross income, the net returns obtained was found out using the formula:

Net income (₹ ha^{-1}) = Gross income - cost of cultivation

3.4.15.2 Benefit : Cost Ratio (BCR)

B:C ratio of the treatments were calculated using the formula

$$BCR = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.4.16 Statistical Analysis

The experimental data generated were analyzed statistically by applying the technique of analysis of variance (ANOVA) for Randomized Block Design experiment for the first experiment and ANOVA for split plot design for the second experiment and the significance was tested by F test (Cochran and Cox, 1965). Critical difference (CD) is provided wherever the F test was significant.

RESULTS

4. RESULTS

The study entitled 'Productivity enhancement of blackgram (*Vigna mungo* (L.) Hepper) intercropped in coconut gardens' was undertaken at the Instructional Farm attached to College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during 2019 - 2021. The research programme aimed to identify shade tolerant blackgram varieties suitable for coconut gardens, to study the effect of foliar nutrition and plant growth regulators on growth and yield of the shade tolerant blackgram varieties intercropped in coconut garden and to work out the economics of cultivation. The study was conducted as two separate experiments. In experiment I, blackgram varieties and cultures were collected and micro plots were laid out in randomized block design with three replications. In experiment II, five shade tolerant, high yielding varieties were selected and laid out in split plot design with varieties as the main plot treatments and foliar spray (6 nos) as the subplot treatments with four replications. The data collected were tabulated, analyzed statistically and the results obtained are detailed in this chapter.

4.1 EXPERIMENT I: SCREENING OF BLACKGRAM VARIETIES FOR SHADE TOLERANCE (MICRO PLOT STUDY)

4.1.1 Growth Characters

Growth characters *viz.*, plant height, number of branches per plant and number of leaves per plant (at monthly intervals), leaf area index, number of nodules per plant and dry weight of nodules per plant (at flowering) were recorded.

4.1.1.1 Plant Height

The data on plant height (at monthly intervals) of blackgram varieties and cultures screened for shade tolerance in coconut garden are presented in Table 3.

Table 3. Plant height of blackgram varieties and cultures screened for shade tolerance at monthly interval, cm

Treatments	1 MAS	2 MAS	At harvest
T_1 - Sumanjana	44.34	85.10	96.83
T_2 - DU 1	41.17	70.27	73.63
T_3 - DBGV 5	47.70	87.97	96.89
T_4 - Culture 4.6.1	38.79	76.83	86.17
T_5 - Culture 4.5.8	33.77	59.06	62.77
T_6 - Culture 4.5.18	32.17	65.17	77.77
T_7 - VBN 6	43.86	79.66	91.53
T_8 - VBN 8	35.66	62.94	69.20
T_9 - VBN 5	43.33	83.33	95.73
T_{10} - TAU 2	39.00	66.50	70.23
T_{11} - Rashmi	40.13	73.60	75.50
T_{12} - CO 6	47.44	85.80	95.33
T_{13} - Blackgold	40.17	67.26	71.13
T_{14} - TAU 1	40.84	74.43	78.44
T_{15} - AKU 15	40.03	77.82	79.17
SEm(±)	1.27	2.77	2.76
CD (0.05)	3.686	8.065	8.022

Perusal of the data revealed that plant height differed significantly among varieties and cultures. In general, plant height increased with growth among varieties and cultures and, DBGV 5 recorded taller plants during the entire cropping period. At 1 month after sowing (MAS), DBGV 5 recorded plant height of 47.70 cm and was on par with CO 6 (47.44 cm) and Sumanjana (44.34 cm). However, the plants were relatively shorter in Culture 4.5.18 (32.17 cm), Culture 4.5.8 (33.77 cm) and VBN 8 (35.66 cm) and was on par with each other. At 2 MAS, taller plants were recorded by DBGV 5 (87.97 cm) and was on par with CO 6 (85.80 cm), Sumanjana (85.10 cm) and VBN 5 (83.33 cm). At the time of harvest also, taller plants were observed in DBGV 5 (96.89 cm) and was on par with Sumanjana (96.83 cm), VBN 5 (95.73), CO 6 (95.33) and VBN 6 (91.53 cm). Overall, the plants were the shortest in Culture 4.5.8 (62.77 cm) and TAU 2 (70.23 cm).

4.1.1.2 Number of Leaves per Plant

The number of trifoliate leaves per plant produced at monthly intervals among blackgram varieties and cultures screened are presented in Table 4.

The number of leaves per plant from 1 MAS to harvest showed significant variation among the varieties and cultures. The number of leaves increased up to 2 MAS and showed a decreasing trend towards harvest. At 1 MAS, the number of leaves produced per plant among varieties and cultures ranged between 4 to 7.6. The variety DBGV 5 produced higher number of leaves per plant (7.56) which was comparable with CO 6 (7.3), Sumanjana (7.3), VBN 6 (7) and VBN 5 (6.8). In general, number of leaves was lower in cultures and the lowest number of leaves per plant was registered by the Culture 4.5.18 (4). However, at 2 MAS, no significant difference in number of leaves per plant was observed among varieties and cultures. Even though the leaf production capacity and leaf persistence of each variety and culture were lower at the time of harvest, there existed significant difference in number of leaves among varieties and cultures. Plants with more number of leaves

Table 4. Number of leaves per plant of blackgram varieties and cultures screened for shade tolerance at monthly interval

Treatments	1 MAS	2 MAS	At harvest
T_1 - Sumanjana	7.3	11.0	5.2
T_2 - DU 1	6.1	12.0	6.8
T_3 - DBGV 5	7.6	12.1	6.7
T_4 - Culture 4.6.1	5.7	12.2	6.2
T_5 - Culture 4.5.8	5.4	10.8	8.1
T_6 - Culture 4.5.18	4.0	10.8	8.6
T_7 - VBN 6	7.0	11.2	6.8
T_8 - VBN 8	5.9	11.1	5.7
T_9 - VBN 5	6.8	11.8	6.2
T_{10} - TAU 2	6.1	11.1	7.9
T_{11} – Rashmi	5.7	10.9	7.7
T_{12} - CO 6	7.3	13.0	6.8
T_{13} - Blackgold	6.1	10.8	6.4
T_{14} - TAU 1	6.1	10.5	4.3
T_{15} - AKU 15	6.3	10.1	5.2
SEm(±)	0.4	0.8	0.6
CD (0.05)	1.18	NS	1.76

NS - Not significant MAS - Months after sowing was observed in the Culture 4.5.18 (8.6) and was on par with the Culture 4.5.8 (8.1) and varieties, TAU 2 (7.9) and Rashmi (7.7).

4.1.1.3 Number of Branches per Plant

The data in Table 5 represents the number of branches per plant at monthly intervals among the varieties and cultures. It can be seen that the varieties and cultures significantly differed in number of branches per plant at 1 MAS only.

Among the varieties and cultures tested, the varieties TAU 1 and AKU 15 exhibited branching habit compared to other varieties and cultures with an average of 1.5 and 1.3 branches per plant respectively. Apart from these two, all the varieties recorded single branch and were at par with each other. In the later stages of plant growth, upto harvest the number branches per plant showed no significant difference among the varieties and cultures.

4.1.1.4 Leaf Area Index at Flowering

Table 6 shows the data on variation in leaf area index (LAI) at flowering among the blackgram varieties and cultures intercropped in coconut garden. The LAI computed varied significantly among the varieties and cultures and value ranged between 3.36 to 5.77. The variety CO 6 recorded higher LAI of 5.77 which was comparable with DBGV 5 (5.36) followed by Sumanjana (4.88). The lower value of LAI was recorded by the variety TAU 1 (3.36) and was on par with Blackgold (3.43), AKU 15 (3.45), Reshmi (3.48) and Culture 4.5.18 (3.5), Culture 4.6.1 (3.52) and Culture 4.5.8 (3.90).

4.1.1.5 Number of Nodules per Plant at Flowering

The data on number of nodules per plant at flowering varied significantly due to varieties and cultures and is given in Table 6. There was no significant difference

Table 5. Number of branches per plant of blackgram varieties and cultures screened for shade tolerance at monthly interval

Treatments	1 MAS	2 MAS	At harvest
T_1 - Sumanjana	1.0	2.4	2.4
T_2 - DU 1	1.0	2.9	3.0
T_3 - DBGV 5	1.0	2.3	2.5
T_4 - Culture 4.6.1	1.0	2.2	2.5
T_5 - Culture 4.5.8	1.0	2.8	3.0
T_6 - Culture 4.5.18	1.0	2.3	3.3
T_7 - VBN 6	1.0	2.2	2.7
T_8 - VBN 8	1.0	2.4	2.8
T_9 - VBN 5	1.0	2.2	2.3
T_{10} - TAU 2	1.0	2.5	2.5
T_{11} - Rashmi	1.0	2.2	2.7
T_{12} - CO 6	1.0	2.7	2.4
T_{13} - Blackgold	1.0	1.8``	2.2
T_{14} - TAU 1	1.5	1.8	2.1
T_{15} - AKU 15	1.3	2.1	2.6
SEm(±)	0.1	0.3	0.3
CD (0.05)	0.26	NS	NS

NS - Not significant MAS - Months after sowing

Table 6. LAI, number of nodules and dry weight of nodules of blackgram varieties and cultures screened for shade tolerance at flowering

Treatments	Leaf area index	Number of nodules per plant	Dry weight of nodules per plant (g)
T_1 - Sumanjana	4.88	18.33	0.41
T_2 - DU 1	4.54	18.67	0.53
T_3 - DBGV 5	5.36	17.00	0.49
T_4 - Culture 4.6.1	3.52	17.33	0.51
T_5 - Culture 4.5.8	3.90	16.33	0.48
T_6 - Culture 4.5.18	3.50	17.33	0.51
T_7 - VBN 6	4.86	20.67	0.53
T_8 - VBN 8	4.48	17.67	0.49
T_9 - VBN 5	4.66	24.00	0.46
T_{10} - TAU 2	4.45	19.00	0.54
T_{11} - Rashmi	3.48	19.00	0.53
T_{12} - CO 6	5.77	22.00	0.33
T_{13} - Blackgold	3.43	23.33	0.53
T_{14} - TAU 1	3.36	19.67	0.36
T_{15} - AKU 15	3.45	20.67	0.44
SEm(±)	0.28	1.79	0.06
CD (0.05)	0.809	NS	NS

NS - Not significant

observed in number of nodules per plant among the varieties and cultures considered under this study.

4.1.1.6 Dry Weight of Nodules per Plant at Flowering

The perusal of data in Table 6 revealed that, similar to number of nodules per plant at flowering, dry weight of nodules per plant at flowering marked no variation among the varieties and cultures under partially shaded coconut garden.

4.1.2 Root Characters (At Harvest)

The data on root characters *viz.*, rooting length, root volume and root dry weight were recorded at harvest and are presented in Table 7.

4.1.2.1 Rooting Length, Root Volume and Root Dry Weight

There was no significant variation in rooting length, root volume and root dry weight (at harvest) among the blackgram varieties and cultures evaluated under partially shaded coconut garden.

4.1.3 Physiological Characters (At Flowering)

The physiological characters *viz.*, photosynthetic rate, leaf area duration, stomatal index, chlorophyll content and proline content at flowering were recorded and analyzed.

4.1.3.1 Photosynthetic Rate

The data presented in Table 8 represents the variation in photosynthetic rate at flowering among varieties and cultures screened for shade in coconut garden.

The photosynthetic rate recorded wide variation among the varieties and cultures tested and the values ranged from 1.13 µ moles CO_2 m^{-2} s^{-1} to 8.97 µ moles

Table 7. Root characters of blackgram varieties and cultures screened for shade tolerance at harvest

Treatments	Rooting length (cm)	Root volume (cm^3)	Root dry weight (g per plant)
T_1 – Sumanjana	21.33	6.67	2.02
T_2 - DU 1	22.13	6.33	2.03
T_3 - DBGV 5	25.17	7.10	2.24
T_4 - Culture 4.6.1	20.33	7.00	2.10
T_5 - Culture 4.5.8	25.33	6.33	2.25
T_6 - Culture 4.5.18	20.33	5.87	2.01
T_7 - VBN 6	28.50	5.43	2.23
T_8 - VBN 8	22.33	7.07	2.13
T_9 - VBN 5	22.67	6.07	2.14
T_{10} - TAU 2	21.00	5.97	2.20
T_{11} - Rashmi	21.33	7.00	2.18
T_{12} - CO 6	22.67	6.67	2.27
T_{13} - Blackgold	21.67	5.33	2.27
T_{14} - TAU 1	23.67	7.33	2.23
T_{15} - AKU 15	22.67	4.67	2.23
SEm(±)	1.65	0.93	0.063
CD (0.05)	NS	NS	NS

NS - Not significant

CO_2 m^{-2} s^{-1}. The photosynthetic rate (8.97 µ moles CO_2 m^{-2} s^{-1}) recorded was the highest for the varieties DBGV 5 and VBN 5, followed by CO 6 (8.27 µ moles CO_2 m^{-2} s^{-1}). The lowest value was registered by the variety TAU 1 (1.13 µ moles CO_2 m^{-2} s^{-1}) and was on par with AKU 15 (1.47 µ moles CO_2 m^{-2} s^{-1}).

4.1.3.2 Leaf Area Duration

The effect of varieties and cultures on leaf area duration (LAD) is presented in Table 8. Leaf area duration varied significantly among varieties and cultures and the value ranged from 34.89 days to 65.66 days. LAD was found to be higher for the variety CO 6 (65.66 days) and was on par with DBGV 5 (58.40 days). The lower value of LAD was registered by the variety TAU 1 (34.89 days) and was on par with Culture 4.5.8 (43.08 days), AKU 15 (41.5 days), Culture 4.6.1 (41.28 days), Rashmi (37.77 days), Blackgold (35.75 days) and Culture 4.5.18 (35.34 days).

4.1.3.3 Stomatal Index

The data presented in Table 8 shows the effect of varieties and cultures on stomatal index at flowering. There was significant variation in stomatal index at flowering among the varieties and cultures. The variety DBGV 5 recorded higher stomatal index (23.33%) which was on par with TAU 2 (22.10%), Sumanjana (20.80%) and VBN 8 (20.03%). Lower value of stomatal index was registered by the variety Rashmi (15.44%) which was on par with the rest of the varieties and cultures except VBN 6.

4.1.3.4 Chlorophyll Content

Table 9 shows the effect of varieties and cultures on chlorophyll a, b and total chlorophyll at flowering. Significant variation in chlorophyll a, b and total chlorophyll contents were observed among the varieties and cultures under evaluation. Chlorophyll a was found higher for the variety DBGV 5 (1.91 mg g^{-1}

Table 8. Photosynthetic rate, leaf area duration and stomatal index of blackgram varieties and cultures screened for shade tolerance at flowering

Treatments	Photosynthetic rate (µ moles CO_2 m^{-2} s^{-1})	Leaf area duration (days)	Stomatal index (%)
T_1 – Sumanjana	6.93	50.83	20.80
T_2 - DU 1	4.43	47.47	17.55
T_3 - DBGV 5	8.97	58.40	23.33
T_4 - Culture 4.6.1	6.00	41.28	17.08
T_5 - Culture 4.5.8	3.83	43.08	16.79
T_6 - Culture 4.5.18	5.90	35.34	16.85
T_7 - VBN 6	6.97	53.48	19.75
T_8 - VBN 8	5.70	48.06	20.03
T_9 - VBN 5	8.97	49.22	16.95
T_{10} - TAU 2	7.00	48.16	22.10
T_{11} - Rashmi	6.77	37.77	15.44
T_{12} - CO 6	8.27	65.66	18.53
T_{13} - Blackgold	4.03	35.75	18.16
T_{14} - TAU 1	1.13	34.89	15.45
T_{15} - AKU 15	1.47	41.50	17.48
SEm(±)	0.20	2.93	1.21
CD (0.05)	0.587	8.542	3.450

Table 9. Chlorophyll and proline content of blackgram varieties and cultures screened for shade tolerance at flowering

Treatments	Chlorophyll a (mg g^{-1} fresh tissue)	Chlorophyll b (mg g^{-1} fresh tissue)	Total chlorophyll (mg g^{-1} fresh tissue)	Proline content (ug proline mL^{-1})
T_1 – Sumanjana	1.86	0.62	3.19	0.041
T_2 - DU 1	1.38	0.70	2.09	0.038
T_3 - DBGV 5	1.91	0.53	3.25	0.034
T_4 - Culture 4.6.1	1.31	0.54	1.86	0.033
T_5 - Culture 4.5.8	1.39	0.54	1.83	0.031
T_6 - Culture 4.5.18	1.30	0.88	2.30	0.037
T_7 - VBN 6	1.60	0.65	2.75	0.031
T_8 - VBN 8	1.53	0.91	2.40	0.036
T_9 - VBN 5	1.50	0.83	2.83	0.035
T_{10} - TAU 2	1.29	0.64	2.50	0.036
T_{11} - Rashmi	1.35	0.70	2.65	0.038
T_{12} - CO 6	1.58	0.70	2.66	0.030
T_{13} - Blackgold	1.31	0.67	2.63	0.040
T_{14} - TAU 1	1.44	0.79	2.71	0.045
T_{15} - AKU 15	1.39	0.71	2.11	0.043
SEm(±)	0.07	0.058	0.16	0.003
CD (0.05)	0.210	0.169	0.450	NS

NS - Not significant

fresh tissue) and was on par with Sumanjana (1.86 mg g^{-1} fresh tissue). On the other hand, chlorophyll b was recorded higher by the variety VBN 8 (0.91 mg g^{-1} fresh tissue) and was on par with Culture 4.5.18 (0.88 mg g^{-1} fresh tissue),VBN 5 (0.83 mg g^{-1} fresh tissue) and TAU 1 (0.79 mg g^{-1} fresh tissue). The total chlorophyll followed the same trend as that of chlorophyll a and the variety DBGV 5 recorded higher value of total chlorophyll (3.25 mg g^{-1} fresh tissue) and was on par with Sumanjana (3.19 mg g^{-1} fresh tissue) and VBN 5 (2.83 mg g^{-1} fresh tissue).

4.1.3.5 Proline Content

The data on variation in proline content at flowering among the varieties and cultures is presented in Table 9. The blackgram varieties and cultures intercropped in coconut garden had shown no significant variation in proline and the content was negligible.

4.1.4 Yield Parameters

The data on days to 50 per cent flowering, yield attributes like, number of pods per plant, average length of pod, number of seeds per pod, 100 seed weight, seed yield per plant and haulm yield per plant were summarized in Table 10.

4.1.4.1 Days to 50 per cent Flowering

There was significant difference among the varieties and cultures tested with respect to days to 50 per cent flowering. The variety Sumanjana and the Culture 4.6.1 flowered early compared to other varieties and took 34 days to reach 50 per cent flowering. The variety DBGV 5 which reached 50 per cent flowering at 36 DAS was on par with Sumanjana and Culture 4.6.1. TAU 2 took the maximum number of days (43.33 days) to reach 50 per cent flowering and was on par with VBN 5, VBN 6, DU 1, Rashmi and Culture 4.5.18.

4.1.4.2 Number of Pods per Plant

Table 10 depicts the significant variation in number of pods per plant among the varieties and cultures evaluated. The variety DBGV 5 produced the higher number of pods per plant (23.67) and was on par with CO 6 (22.55), VBN 5 (22), VBN 6 (20.45) Sumanjana (20.55) and Rashmi (20.80) under partially shaded coconut garden. The lowest number of number of pods per plant was recorded by the Culture 4.5.8 (12.70) which was on par with VBN 8 (14.65), DU 1 (16.65), Blackgold (16.83), TAU 1 (17.16) and Culture 4.5.18 (17.30).

4.1.4.3 Number of Seeds per Pod

It is evident from Table 10 that varietal difference was not significant for number of seeds per pod.

4.1.4.4 Average Length of Pod

Similar to number seed per pod, average length of pod also did not vary significantly among the varieties and cultures (Table 10). The average pod length ranged between 4.22 cm to 4.54 cm among the varieties and cultures.

4.1.4.5 Hundred Seed Weight

Hundred seed weight is an important yield determining character of a variety and it varied significantly among the varieties and cultures. The Culture 4.6.1 produced bold seeds with the highest 100 seed weight (5.06 g) and was on par with DBGV 5 (5.01 g), DU 1 (4.70 g), Blackgold (4.96 g), TAU 1 (4.89 g) and AKU 15 (4.84 g) under coconut garden. Lower value of 100 seed weight was produced by the Culture 4.5.8 (3.85 g) and was on par with VBN 8 (3.93 g), Culture 4.5.18 (4.02 g) and Sumanjana (4.13 g).

4.1.4.6 Seed Yield per Plant

The observation on seed yield per plant registered significant variation among varieties and cultures (Table 10). The seed yield per plant varied between 2.16 g to 5.44 g among the varieties and cultures considered. The highest seed yield was recorded by the variety DBGV 5 (5.44 g) followed by VBN 5 (4.44 g) and Sumanjana (4.40 g). Lowest seed yield was recorded by the Culture 4.5.8 (2.16 g).

4.1.4.7 Haulm Yield per Plant

The Table 10 depicts the variation in haulm yield per plant among varieties and cultures evaluated under shade. There was significant variation on haulm yield per plant among the varieties and cultures and the variety DBGV 5 recorded higher value of haulm yield (19.0 g) and was on par with VBN 5 (17.43 g), Sumanjana (17 g) and CO 6 (17 g). Lower value of haulm yield per plant was registered by the Culture 4.5.8 (11.20 g) and was on par with all other varieties except VBN 6.

4.1.4.8 Seed Yield

The Table 11 depicts the variation in seed yield (kg ha^{-1}) among varieties and cultures evaluated under shade. Superior seed yield was produced by the variety DBGV 5 (1183 kg ha^{-1}), followed by VBN 5 (917 kg ha^{-1}), Sumanjana (907 kg ha^{-1}), CO 6 (863 kg ha^{-1}) and VBN 5 (853 kg ha^{-1}) The Culture 4.5.8 produced significantly lower value of seed yield (310 kg ha^{-1}).

4.1.4.9 Haulm Yield

Haulm yield also varied significantly among the varieties and cultures tested (Table 11). Significantly higher haulm yield was produced by the variety DBGV 5 (4194 kg ha^{-1}) followed by VBN 8 (4015 kg ha^{-1}).

Table 10. Yield attributes and yield of blackgram varieties and cultures screened for shade tolerance

Treatments	Days to 50% flowering	Number of pods per plant	Number of seeds per pod	Average length of pod (cm)	100 seed weight (g)	Seed yield per plant (g)	Haulm yield per plant (g)
T_1 - Sumanjana	34.33	20.55	6.7	4.34	4.13	4.40	17.00
T_2 - DU 1	41.67	16.65	7.1	4.48	4.70	3.19	12.00
T_3 - DBGV 5	36.33	23.67	6.5	4.41	5.01	5.44	19.00
T_4 - Culture 4.6.1	34.33	17.75	6.4	4.39	5.06	3.84	12.00
T_5 - Culture 4.5.8	38.00	12.70	6.5	4.33	3.85	2.16	11.20
T_6 - Culture 4.5.18	43.00	17.30	7.1	4.22	4.02	3.39	12.83
T_7 - VBN 6	42.33	20.45	7.3	4.58	4.29	4.20	16.30
T_8 - VBN 8	39.67	14.65	6.9	4.35	3.93	4.06	12.33
T_9 - VBN 5	42.67	22.00	6.7	4.36	4.46	4.44	17.43
T_{10} - TAU 2	43.33	18.40	6.7	4.48	4.59	3.53	13.13
T_{11} - Rashmi	43.00	20.80	7.0	4.45	4.50	3.59	12.47
T_{12} - CO 6	37.67	22.55	7.0	4.54	4.40	4.24	17.00
T_{13} - Blackgold	38.67	16.83	6.9	4.48	4.96	3.88	12.33
T_{14} - TAU 1	38.33	17.16	6.7	4.48	4.89	4.03	11.83
T_{15} - AKU 15	36.67	17.67	7.1	4.29	4.84	4.03	12.50
SEm(±)	0.74	1.69	0.2	0.13	0.14	0.26	0.88
CD (0.05)	2.152	4.922	NS	NS	0.422	0.784	2.510

NS - Not significant

4.1.4.10 Harvest Index

The data on harvest index among varieties and cultures is presented in Table 11. There was significant variation in harvest index among the varieties and cultures. The variety Sumanjana (0.24) recorded higher value of harvest index which was on par with DBGV 5 (0.23), VBN 6 (0.21), DU 1 (0.19) and VBN 5 (0.19). Lowest value of harvest index was registered by the Culture 4.5.18 (0.11).

4.1.5 Dry Matter Partitioning at Harvest (g per plant)

The observational plants were pulled out and all the parts *viz.*, shoot, leaf, root, pod and seeds were separated, dried, weighed and the mean data was analyzed which is summarized in Table 12.

4.1.5.1 Shoot Dry Weight per Plant

Shoot dry weight varied significantly among varieties and cultures evaluated. The Culture 4.5.8 recorded the highest shoot weight per plant (7.463 g) followed by VBN 8 (7.253 g). Lowest shoot dry weight per plant was recorded by the variety Sumanjana (3.033 g).

4.1.5.2 Root Dry Weight per Plant

There was no significant variation in root dry weight among the varieties and cultures tested (Table 12).

4.1.5.3 Leaf Dry Weight per Plant

There was significant difference in leaf dry weight among the varieties and cultures. The highest value of leaf dry weight per plant was recorded by the Culture 4.5.18 (5.03 g) followed by AKU 15 (5.01 g) while it was low in Sumanjana (1.95 g).

Table 11. Seed yield, haulm yield and harvest index of blackgram varieties and cultures screened for shade tolerance

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
T_1 – Sumanjana	907	2,800	0.24
T_2 - DU 1	583	2,487	0.19
T_3 - DBGV 5	1183	4,194	0.23
T_4 - Culture 4.6.1	757	3,534	0.18
T_5 - Culture 4.5.8	310	2,535	0.11
T_6 - Culture 4.5.18	637	3,389	0.16
T_7 - VBN 6	853	3,204	0.21
T_8 - VBN 8	817	4,015	0.17
T_9 - VBN 5	917	4,000	0.19
T_{10} - TAU 2	673	3,099	0.18
T_{11} - Rashmi	690	3,411	0.17
T_{12} - CO 6	863	3,814	0.18
T_{13} - Blackgold	767	3,444	0.18
T_{14} - TAU 1	807	3,575	0.18
T_{15} - AKU 15	807	3,871	0.17
SEm(±)	72.0	45.17	0.02
CD (0.05)	209.5	131.528	0.050

Table 12. Drymatter partitioning and total dry matter production (TDMP) of blackgram varieties and cultures screened for shade tolerance at harvest (g per plant)

Treatments	Shoot weight	Root weight	Leaf weight	Pod weight	Seed weight	TDMP
T_1 - Sumanjana	3.03	2.02	1.95	6.60	3.90	13.57
T_2 - DU 1	3.48	2.03	2.97	4.78	2.69	13.23
T_3 - DBGV 5	5.60	2.24	3.33	8.16	4.94	19.30
T_4 - Culture 4.6.1	5.95	2.10	4.09	5.76	3.34	17.87
T_5 - Culture 4.5.8	7.46	2.25	4.61	3.25	1.67	17.53
T_6 - Culture 4.5.18	6.08	2.01	5.03	5.08	2.89	18.17
T_7 - VBN 6	4.93	2.23	2.40	6.30	3.70	15.83
T_8 - VBN 8	7.25	2.13	4.83	6.09	3.56	20.27
T_9 - VBN 5	5.79	2.14	4.91	6.66	3.94	19.47
T_{10} - TAU 2	4.38	2.20	4.56	5.29	3.03	16.40
T_{11} - Rashmi	5.44	2.18	4.30	5.38	3.09	17.27
T_{12} - CO 6	5.82	2.27	3.31	6.36	3.74	17.73
T_{13} - Blackgold	5.03	2.27	4.24	5.82	3.38	17.33
T_{14} - TAU 1	4.41	2.23	4.92	6.04	3.53	17.57
T_{15} - AKU 15	6.84	2.23	5.01	6.26	3.53	20.3
SEm(±)	0.001	0.063	0.001	0.27	0.27	0.72
CD (0.05)	0.0040	NS	0.002	0.785	0.786	2.06

NS - Not significant

4.1.5.4 Pod Dry Weight per Plant

There was significant variation in pod dry weight among the varieties and cultures when intercropped in coconut garden. The highest pod dry weight was recorded by the variety DBGV 5 (8.16 g) followed by VBN 5 (6.66 g) and Sumanjana (6.60 g). The lowest value of pod dry weight (3.25 g) per plant was recorded by the Culture 4.5.8.

4.1.5.5 Seed Dry Weight per Plant

Seed dry weight varied significantly among the varieties and cultures and Superior value was recorded in the variety DBGV 5 (4.94 g) followed by VBN 5 (3.94 g) and Sumanjana (3.9 g). The Culture 4.5.8 recorded the lowest seed dry weight per plant (1.67 g).

4.1.5.6 Total Dry Matter Production (TDMP)

Significant variation in total dry matter production was observed among the varieties and cultures tested. The higher TDMP was recorded by the variety AKU 15 (20.3 g per plant) which was on par with VBN 8 (20.27 g per plant), VBN 5 (19.47 g per plant) and DBGV 5 (19.3 g per plant). The variety DU 1 recorded lower value of TDMP (13.23 g per plant) which was on par with Sumanjana (13.57 g per plant).

4.1.6 Light Intensity (klux) and Photosynthetically Active Radiation (µ moles s^{-1} m^{-2}) at Monthly Interval

Table 13a represents the mean values of light intensity and PAR recorded during the cropping period (2nd October 2019 to 10th January 2020) at monthly interval under coconut garden. The light intensity during the entire cropping period ranged from (44.1± 2.26) klux to (45.73± 2.89) klux. On the other hand, PAR varied from sowing till harvest. It increased from 1 MAS to 2 MAS and then showed a decreasing trend towards harvest. At 2 MAS, PAR recorded the highest value of (9.89 ± 0.12) µ moles s^{-1} m^{-2} later at harvest it decreased to (4.70 ± 0.43) µ moles s^{-1} m^{-2}.

4.1.7 Characters Identified for Shade Tolerance in Blackgram

Based on Experiment I, growth and physiological characters for shade tolerance in blackgram was identified and are presented in Table 13b. The varieties DBGV 5, VBN 5, Sumanjana, VBN 6 and CO 6 were found to perform better in shaded coconut garden with increased plant height (91.53 cm to 96.89 cm), leaf area index (4.66 to 5.77), leaf area duration (49.22 days to 65.6 days), total chlorophyll content (2.30 mg g^{-1} fresh tissue to 3.25 mg g^{-1} fresh tissue) and photosynthetic rate (6.93 µ moles CO_2 m^{-2} sec^{-1} to 8.97 µ moles CO_2 m^{-2} sec^{-1}). These five varieties reached 50 per cent flowering earlier (36.33 days to 42.67 days) compared to other varieties and cultures.

4.1.8 Selection of Varieties Experiment II

The varieties which performed well in the partially shaded coconut garden were selected based on growth, yield attributing characters and yield. The variety DBGV 5, VBN 5, Sumanjana, CO 6 and VBN 6 were identified as better performers under partial shaded coconut garden with seed yields of 1183 kg ha^{-1}, 917 kg ha^{-1}, 907 kg ha^{-1}, 863 kg ha^{-1} and 853 kg ha^{-1} respectively. These varieties were further evaluated for their response to foliar nutrition and growth regulators in coconut garden under partial shade.

Table 13a. Light intensity and photosynthetically active radiation (PAR) in coconut garden during the crop growth period at monthly interval

	Light intensity (klux)	PAR (μ moles s^{-1} m^{-2})
1 MAS	45.73 ± 2.89	5.11 ± 0.70
2 MAS	44.16 ± 2.92	9.89 ± 0.12
At harvest	44.1 ± 2.26	4.70 ± 0.43

MAS - Months after sowing

Table 13b. Growth and physiological characters identified for shade tolerance in blackgram

	Plant height (cm)	LAI	LAD (days)	Total chlorophyll content (mg g^{-1} fresh tissue)	Photosynthetic rate (μ moles CO_2 m^{-2} sec^{-1})	Days to 50% flowering
DBGV 5	96.89	5.36	58.40	3.25	8.97	36.33
VBN 5	95.73	4.66	49.22	2.85	8.97	42.67
Sumanjana	96.83	4.88	50.83	3.19	6.93	34.33
VBN 6	91.53	4.86	53.48	2.30	6.97	42.33
CO 6	95.33	5.77	65.66	2.66	8.27	37.67

4.2 EXPERIMENT II: PERFORMANCE EVALUATION OF SHADE TOLERANT VARIETIES UNDER FOLIAR APPLICATION OF NUTRIENTS AND GROWTH REGULATORS IN RAINFED COCONUT GARDEN

The experiment was conducted during summer season of 2020 and the confirmatory trial during *Rabi* 2020-21.

4.2.1 Growth Attributes

Growth characters *viz.*, plant height, number of leaves per plant and number of branches per plant at monthly interval; and LAI, number and dry weight of nodules per plant at flowering were recorded for two seasons.

4.2.1.1 Plant Height

The results on the effect of varieties, foliar application of nutrients and plant growth regulators and their interaction on plant height at monthly interval for two seasons are presented in Tables 14a and 14b.

The effect of varieties on plant height was found to be significant at all the growth stages during both the seasons. Among the varieties, tallest plants were recorded for Sumanjana (53.27 cm) at 1 MAS during summer season. However, during *Rabi*, Sumanjana and CO 6 were significantly taller with mean heights of 51.57 cm and 51.23 cm respectively. At 2 MAS, tallest plants were observed for VBN 6 (85.89 cm) during summer and Sumanjana and DBGV 5 during *Rabi* (72.48 cm and 72.41 cm respectively). At harvest, taller plants were recorded for CO 6 and Sumanjana (89.57 cm and 87.75 cm respectively) during summer while plants of Sumanjana were the tallest in *Rabi* (83.74 cm).

The effect of foliar spray of nutrients and plant growth regulators was found to be significant at 2 MAS and at harvest during both the seasons. Plants which received

Table 14a. Effect of varieties and foliar application on plant height during summer 2020 and *Rabi* 2020-21, cm

Treatments	Plant height					
	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	1 MAS	2 MAS	At harvest	1 MAS	2 MAS	At harvest
v_1 - Sumanjana	53.27	72.28	87.75	51.57	72.48	83.74
v_2 - DBGV 5	45.01	75.52	82.67	49.77	72.41	80.46
v_3 - VBN 5	46.19	77.95	85.40	47.00	59.31	66.61
v_4 - VBN 6	50.23	85.89	83.71	47.81	57.11	63.94
v_5 - CO 6	51.39	80.53	89.57	51.23	64.30	72.20
SEm(±)	0.46	0.72	0.72	0.52	0.66	0.74
CD (0.05)	1.410	2.211	2.211	1.593	2.029	2.288
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	49.52	75.52	84.52	48.95	64.2	72.03
f_2 - Foliar spray of SOP @ 0.5%	48.40	72.28	81.28	48.97	61.11	68.82
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	48.93	77.95	86.95	50.89	68.04	76.72
f_4 - $f_3 + f_1$	49.44	85.89	94.89	49.87	71.02	79.92
f_5 - $f_3 + f_2$	49.41	80.53	89.53	49.35	67.90	76.82
f_6 - Control (KAU POP)	49.60	68.76	77.76	48.83	58.37	66.04
SEm(±)	0.426	0.59	0.59	0.61	0.86	1.02
CD (0.05)	NS	1.672	1.670	NS	2.420	2.865

NS - Not significant MAS – Months after sowing f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 14b. Interaction effect of varieties and foliar application on plant height during summer 2020 and *Rabi* 2020-21, cm

Treatments	Plant height					
	Summer 2020			*Rabi* 2020-21		
	1 MAS	2 MAS	At harvest	1 MAS	2 MAS	At harvest
v_1f_1	45.01	77.15	86.15	52.05	74.21	83.14
v_1f_2	55.67	75.22	84.22	51.56	65.88	84.08
v_1f_3	52.00	80.66	89.66	51.29	74.59	83.86
v_1f_4	52.72	88.70	97.70	53.21	81.40	91.45
v_1f_5	52.51	84.05	93.05	50.40	75.72	85.10
v_1f_6	52.23	66.73	75.73	50.93	63.10	74.82
v_2f_1	45.06	72.78	81.78	47.14	74.96	84.41
v_2f_2	43.18	69.18	78.18	49.88	73.86	73.99
v_2f_3	45.08	75.40	84.40	51.84	74.06	84.83
v_2f_4	44.20	84.84	93.84	50.10	74.54	84.83
v_2f_5	47.87	77.93	86.93	50.68	73.35	85.10
v_2f_6	44.67	61.88	70.88	49.00	63.69	69.61
v_3f_1	54.50	74.19	83.19	48.89	55.65	62.44
v_3f_2	53.27	72.49	81.49	48.06	54.14	60.74
v_3f_3	46.33	76.44	85.44	49.94	64.74	72.58
v_3f_4	46.34	84.30	93.30	45.28	65.50	73.55
v_3f_5	46.86	80.45	89.45	46.14	62.09	69.89
v_3f_6	45.67	70.55	79.55	43.68	53.76	60.47
v_4f_1	46.11	75.10	84.10	46.58	53.76	59.55
v_4f_2	45.83	70.23	79.23	44.90	53.00	59.47
v_4f_3	46.19	76.21	85.21	48.00	59.44	66.65
v_4f_4	48.23	81.00	90.00	47.56	62.09	69.61
v_4f_5	48.67	76.55	85.55	49.43	61.33	68.75
v_4f_6	49.67	69.15	78.15	50.43	53.00	59.61
v_5f_1	52.83	78.36	87.36	50.10	62.85	70.61
v_5f_2	50.67	74.27	83.27	50.47	58.68	65.82
v_5f_3	51.33	81.05	90.05	53.40	67.39	75.68
v_5f_4	50.23	90.60	99.60	53.20	71.56	80.17
v_5f_5	52.33	83.65	92.65	50.10	67.01	75.24
v_5f_6	51.84	75.48	84.48	50.13	58.31	65.68
SEm(±)	0.98	1.41	1.41	1.35	1.87	2.20
CD (0.05)	2.830	4.060	4.060	NS	5.338	NS

NS - Not significant

foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) were the tallest during both the seasons with mean heights of 85.89 cm and 94.89 cm (summer) 71.02 cm and 79.92 cm (*Rabi*) at 2 MAS and at harvest respectively. The plants managed as per the KAU POP (f_6) recorded lowest plant height of 77.67 cm and 66.04 cm at harvest during summer and *Rabi* respectively.

The interaction between varieties and foliar spray of nutrients and plant growth regulators was found to be significant during summer and at 2 MAS during *Rabi*. Among the interaction, Sumanjana along with foliar spray of SOP (0.5%) at 45 and 60 DAS (v_1f_2) recorded the tallest plants (55.67 cm) and was on par with v_3f_1 and v_3f_2 (54.50 cm and 53.27 cm) during summer. At 2 MAS and at harvest, taller plants were recorded in the treatment combination v_5f_4 (90.60 cm and 99.60 cm) and v_1f_4 (88.70 cm and 97.70 cm) during summer. In the *Rabi* season, significant difference in plant height was observed at 2 MAS and combination of Sumanjana along with 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) produced the tallest plants with mean plant height of 81.40 cm.

4.2.1.2 Number of Branches per Plant

The data on number of branches per plant as influenced by varieties, foliar spray and their interaction at monthly intervals during both the seasons are shown in Tables 15a and 15b.

The results showed significant effect for varieties and foliar application of nutrients and plant growth regulators and their interaction on number of branches at monthly interval. The influence of varieties, showed significant variation at all growth stages during summer while the influence was significant from 2 MAS onwards during *Rabi*. During summer, Sumanjana recorded higher number of branches (2.2 and 2.5) and was on par with CO 6 (2.1and 2.4) at one and 2 MAS respectively. During *Rabi*, at 2 MAS Sumanjana recorded maximum number of branches (2.5) and was superior all the varieties. At harvest, DBGV 5, Sumanjana and CO 6 recorded higher number of branches (3.6, 3.5 and 3.5) and were on par with each other during summer season. However, during *Rabi*, significantly higher number of branches was recorded by Sumanjana (3.7) which was on par with DBGV 5 (3.6).

Among the subplot factors, foliar application exerted significant effect on number of branches during both the seasons from 2 MAS. The treatments, foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded higher number of branches (2.4) and was on par with each other except control (f_6) during summer. However, at harvest, f_4 recorded Superior value (3.8) followed by f_5 and f_2 (3.4 and 3.3 respectively). The lowest number of branches was recorded in control (2.6) at harvest. During *Rabi*, the highest number of branches per plant was observed in f_4 (2.7 and 3.6 at 2 MAS and at harvest respectively).

Among the interactions, v x f exerted significant influence on number of branches per plant at all the growth stages during summer. However, the significance was observed only at 2 MAS in *Rabi*. During summer, the treatment combination v_1f_4 recorded higher number of branches per plant (2.3) and was on par with v_1f_2, v_1f_3, v_1f_6, v_5f_3, v_5f_4 and v_5f_5 at 1 MAS. Sumanjana supplied with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) recorded higher number of branches (3.0) at 2 MAS and was on par with v_1f_1, v_1f_5, v_2f_5, v_3f_3 and v_5f_4. During summer, at harvest, the treatment combinations v_1f_4, v_2f_4, v_5f_4, v_1f_5 and v_2f_3 recorded higher number of branches per plant (4, 4, 4, 3.8 and 3.8 respectively) and were on par with each other. During *Rabi*, v_1f_4 recorded higher number of branches per plant (3.4) and was on par with v_2f_4 and v_5f_4 (2.9 and 2.8 respectively).

Table 15a. Effect of varieties and foliar application on number of branches per plant during summer 2020 and *Rabi* 2020-21

Treatments	Number of branches					
	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	1 MAS	2 MAS	At harvest	1 MAS	2 MAS	At harvest
v_1 – Sumanjana	2.2	2.5	3.5	2.1	2.5	3.8
v_2 - DBGV 5	1.4	2.2	3.6	2.0	2.1	3.6
v_3 - VBN 5	1.2	2.2	2.9	2.0	2.1	3.0
v_4 - VBN 6	1.5	2.1	2.9	2.0	2.1	2.9
v_5 - CO 6	2.1	2.4	3.5	2.0	2.2	3.2
SEm(±)	0.03	0.06	0.04	0.04	0.07	0.04
CD (0.05)	0.101	0.181	0.129	NS	0.204	0.137
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	1.6	2.4	3.3	2.0	2.1	3.2
f_2 - Foliar spray of SOP @ 0.5%	1.7	2.2	3.3	2.0	2.0	3.1
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	1.8	2.3	3.1	2.0	2.3	3.4
f_4 - f_3 + f_1	1.7	2.4	3.8	2.1	2.7	3.6
f_5 - f_3 + f_2	1.7	2.4	3.4	2.0	2.1	3.4
f_6 - Control (KAU POP)	1.6	2.0	2.6	2.0	1.9	3.0
SEm(±)	0.04	0.08	0.05	0.04	0.11	0.42
CD (0.05)	NS	0.218	0.128	NS	0.313	0.119

NS - Not significant MAS – Months after sowing f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 15b. Interaction effect of varieties and foliar application on number of branches per plant during summer 2020 and *Rabi* 2020-21

Treatments	Number of branches					
	Summer 2020			*Rabi* 2020-21		
	1 MAS	2 MAS	At harvest	1 MAS	2 MAS	At harvest
v_1f_1	2.0	2.8	3.4	2.0	2.3	3.7
v_1f_2	2.3	2.0	3.5	2.0	2.5	3.8
v_1f_3	2.2	2.5	3.1	2.1	2.5	3.8
v_1f_4	2.3	3.0	4.0	2.4	3.4	4.1
v_1f_5	2.0	2.6	3.8	2.0	2.0	3.8
v_1f_6	2.3	2.0	3.0	2.1	2.5	3.4
v_2f_1	1.4	2.0	3.4	2.0	2.1	3.8
v_2f_2	1.3	2.3	3.7	2.0	1.4	3.3
v_2f_3	1.5	2.0	3.8	2.0	2.4	3.8
v_2f_4	1.4	2.3	4.0	2.0	3.0	3.8
v_2f_5	1.4	3.0	3.4	2.0	2.2	3.8
v_2f_6	1.3	2.0	3.0	2.0	1.4	3.1
v_3f_1	1.2	2.3	3.1	1.8	2.6	2.8
v_3f_2	1.3	2.3	3.0	2.1	2.3	2.7
v_3f_3	1.4	2.7	2.0	2.0	2.1	3.3
v_3f_4	1.0	2.0	3.7	2.0	2.0	3.3
v_3f_5	1.0	2.0	3.4	2.0	1.6	3.1
v_3f_6	1.3	2.0	2.0	2.0	1.9	2.7
v_4f_1	1.4	2.2	3.2	2.0	1.6	2.7
v_4f_2	1.7	2.4	2.7	2.0	2.0	2.7
v_4f_3	1.5	2.0	3.0	2.0	2.4	3.0
v_4f_4	1.7	2.0	3.4	2.0	2.4	3.1
v_4f_5	1.7	2.0	3.0	2.0	2.3	3.1
v_4f_6	1.3	2.0	2.0	2.0	1.9	2.7
v_5f_1	2.0	2.5	3.2	2.0	1.9	3.2
v_5f_2	2.1	2.3	3.5	2.0	2.0	3.0
v_5f_3	2.3	2.5	3.6	2.0	2.0	3.4
v_5f_4	2.3	2.8	4.0	2.0	2.8	3.6
v_5f_5	2.3	2.3	3.4	2.0	2.4	3.4
v_5f_6	1.9	2.1	3.0	2.0	1.9	2.9
SEm(±)	0.10	0.17	0.10	0.10	0.24	0.10
CD (0.05)	0.280	0.479	0.292	NS	0.671	NS

NS - Not significant MAS – Months after sowing

4.2.1.3 Number of Leaves per Plant

The effect of varieties and foliar spray and their interaction on number of trifoliate leaves at monthly interval over two seasons are presented in Tables 16a and 16b.

Perusal of the data in Table 16a revealed that main plot and subplot factor have significant effect on number of leaves per plant during both the seasons. In summer season, at 1 MAS, Sumanjana (8.2) recorded higher number of leaves and was comparable VBN 6 (7.9). During *Rabi* season, the highest number of leaves per plant was recorded by Sumanjana (9) at 1 MAS. During summer, Sumanjana recorded the highest number of leaves per plant (15.1 and 7.6) at 2 MAS and at harvest respectively. In the *Rabi* season, Sumanjana (13.7 and 6.9) and DBGV 5 (14 and 6.6) produced higher number of leaves and were on par at 2 MAS and at harvest respectively.

Regarding the subplot effect, at 1 MAS, foliar spray of SOP (0.5%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_5) recorded higher number of leaves (8.2) and was on par with f_4 (8.0) and f_3 (8) in the summer season and the highest number of leaves was produced by f_4 (9.1) in *Rabi* season. At 2 MAS, higher number leaves per plant was produced by f_4 and f_5 (14.4 and 14.0 respectively) in the summer season and the highest number of leaves per plant was produced in f_4 (13.5) in the *Rabi* season. At harvest, significantly greater number of leaves per plant was registered in f_4 in both the seasons (7.5 and 6.5 respectively).

The interaction effect of varieties and foliar spray exhibited significant variation with respect to number of leaves per plant during both the seasons. During summer, the treatment combinations, v_1f_3, v_1f_5 and v_1f_4 were on par at 30 DAS (9.3, 9.2 and 9.0 respectively). In *Rabi* season, treatment combinations did not vary significantly at 1 MAS. At 2 MAS, v_1f_4 produced higher number of leaves (17.0) and

Table 16a Effect of varieties and foliar application on number of leaves per plant during summer 2020 and *Rabi* 2020-21

Treatments	Number of leaves					
	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	1 MAS	2 MAS	At harvest	1 MAS	2 MAS	At harvest
v_1 - Sumanjana	8.2	15.1	7.6	9.0	13.7	6.9
v_2 - DBGV 5	7.8	12.0	6.1	8.1	14.0	6.6
v_3 - VBN 5	7.7	12.4	6.0	7.8	11.2	5.5
v_4 - VBN 6	8.0	11.4	6.1	8.1	10.8	5.2
v_5 - CO 6	7.5	13.2	6.7	8.2	12.2	5.9
SEm(±)	0.09	0.13	0.08	0.20	0.12	0.10
CD (0.05)	0.293	0.390	0.242	0.618	0.378	0.310
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	7.8	12.7	6.6	8.1	12.2	5.9
f_2 - Foliar spray of SOP @ 0.5%	7.9	12.7	6.4	8.0	11.6	5.6
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	8.0	13.4	6.8	8.3	12.9	6.3
f_4 - $f_3 + f_1$	8.0	14.4	7.5	9.1	13.5	6.6
f_5 - $f_3 + f_2$	8.2	14.0	6.7	8.2	12.9	6.3
f_6 - Control (KAU POP)	7.8	9.8	4.9	7.7	11.1	5.4
SEm(±)	0.09	0.17	0.084	0.25	0.16	0.07
CD (0.05)	0.266	0.468	0.238	0.694	0.441	0.204

MAS – Months after sowing f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 16b. Interaction effect of varieties and foliar application on number of leaves per plant during summer 2020 and *Rabi* 2020-21

Treatments	Number of leaves					
	Summer 2020			*Rabi* 2020-21		
	1 MAS	2 MAS	At harvest	1 MAS	2 MAS	At harvest
v_1f_1	8.5	14.8	7.4	9.4	14.0	6.8
v_1f_2	8.4	15.0	7.5	7.4	12.5	6.9
v_1f_3	9.3	15.5	7.8	8.9	14.1	6.9
v_1f_4	9.0	17.0	8.5	10.9	15.4	7.5
v_1f_5	9.2	16.0	8.0	8.9	14.3	7.0
v_1f_6	8.3	12.5	6.3	8.7	11.8	6.1
v_2f_1	8.0	12.5	6.5	7.6	14.2	6.9
v_2f_2	7.6	11.0	6.0	8.0	14.3	6.1
v_2f_3	7.7	12.0	6.2	9.1	14.3	7.0
v_2f_4	8.0	13.2	6.6	9.4	14.3	7.0
v_2f_5	7.7	14.0	7.0	7.5	14.3	7.0
v_2f_6	7.7	9.0	4.5	6.6	12.6	5.7
v_3f_1	7.8	11.0	6.0	7.6	10.5	5.1
v_3f_2	8.0	12.4	5.5	8.4	10.2	5.0
v_3f_3	7.7	14.5	7.2	7.9	12.3	6.0
v_3f_4	7.3	15.0	8.0	8.2	12.4	6.0
v_3f_5	8.0	13.4	5.0	7.6	11.8	5.7
v_3f_6	7.3	8.0	4.0	7.3	10.2	5.0
v_4f_1	7.6	11.0	6.0	7.9	10.2	4.9
v_4f_2	7.7	12.9	7.0	8.3	10.0	4.9
v_4f_3	8.0	11.0	6.0	7.9	11.3	5.5
v_4f_4	8.0	12.0	7.0	8.4	11.8	5.7
v_4f_5	8.3	12.6	6.3	8.9	11.6	5.6
v_4f_6	8.3	9.0	4.5	7.5	10.0	4.9
v_5f_1	7.3	14.0	7.2	8.1	11.9	5.8
v_5f_2	7.8	12.0	6.1	8.0	11.1	5.4
v_5f_3	7.3	13.8	7.0	7.6	12.8	6.2
v_5f_4	7.8	15.0	7.5	8.5	13.5	6.6
v_5f_5	7.7	14.0	7.0	8.3	12.7	6.2
v_5f_6	7.4	10.5	5.3	8.4	11.0	5.4
SEm(±)	0.21	0.36	0.19	0.54	0.34	0.18
CD (0.05)	0.616	1.032	0.542	NS	0.982	0.519

NS - Not significant MAS – Months after sowing was on par with v_1f_5 (16.0) in summer season and the highest number of leaves per plant (15.4) was recorded in v_1f_4 in *Rabi*. At harvest, the treatment combination v_1f_4 recorded higher number of leaves per plant (8.5) at harvest during the summer season and was on par with v_1f_5 (8.0) and v_3f_4 (8.0). During *Rabi* season the highest number of leaves per plant (7.5) was recorded in v_1f_4.

4.2.1.4 Leaf Area Index

The variation in leaf area index at flowering due to varieties and foliar spray in during the two seasons are presented in Table 17a and 17b.

The effect of varieties on LAI at flowering was found to be significant during both the seasons. In general, LAI was higher during summer compared to *Rabi* season. Among the varieties, CO 6 recorded maximum LAI (5.60 and 5.08) and was on par with Sumanjana (5.42 and 5.02) during both the seasons. During *Rabi* season, higher LAI recorded in CO 6 was on par with all other varieties, except VBN 5.

Leaf are index was found to be superior in plants treated with foliar application of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) during both the seasons, the values being 5.59 and 5.55 respectively.

The interaction effect of varieties and foliar spray was significant during both the seasons. The treatment combination v_1f_4 recorded maximum LAI (6.71) and remained at par with v_5f_3 (6.54) and v_5f_5 (6.35) during summer season. In the *Rabi* season, the treatment combinations v_1f_4, v_2f_4 and v_3f_4 produced higher LAI (6.10, 6.03 and 5.71 respectively) and were on par with each other.

4.2.1.5 Number of Nodules per Plant

The data on the effect of varieties, foliar spray and their interaction on number

Table 17a. Effect of varieties and foliar application on LAI, number of nodules and dry weight of nodules at flowering during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	LAI	Number of nodules per plant	Dry weight of nodule (g per plant)	LAI	Number of nodules per plant	Dry weight of nodule (g per plant)
v_1 – Sumanjana	5.42	21.32	0.47	5.02	29.32	0.65
v_2 - DBGV 5	3.84	19.63	0.43	4.89	29.98	0.66
v_3 - VBN 5	4.68	17.53	0.39	4.60	24.05	0.53
v_4 - VBN 6	5.27	20.32	0.45	5.06	23.15	0.51
v_5 - CO 6	5.60	21.02	0.46	5.08	26.40	0.58
SEm(±)	0.07	0.25	0.003	0.07	0.20	0009
CD (0.05)	0.219	0.781	0.011	0.207	0.616	0.027
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	4.79	21.39	0.47	4.45	26.06	0.57
f_2 - Foliar spray of SOP @ 0.5%	4.64	17.62	0.39	4.89	24.93	0.55
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	4.98	20.09	0.44	5.23	27.69	0.61
f_4 - f_3 + f_1	5.59	23.51	0.52	5.55	29.25	0.64
f_5 - f_3 + f_2	5.32	20.55	0.45	5.11	27.72	0.61
f_6 - Control (KAU POP)	4.46	16.62	0.37	4.35	23.82	0.52
SEm(±)	0.07	0.27	0.006	0.06	0.35	0.007
CD (0.05)	0.219	0.755	0.018	0.165	0.988	0.021

f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 17b. Interaction effect of varieties and foliar application on LAI, number of nodules and dry weight of nodule per plant at flowering during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
	LAI	Number of nodules	Dry weight of nodule (g)	LAI	Number of nodules	Dry weight of nodule (g)
v_1f_1	4.99	22.61	0.50	4.40	30.08	0.67
v_1f_2	4.29	19.00	0.42	5.15	26.71	0.59
v_1f_3	5.04	21.00	0.46	5.15	30.24	0.66
v_1f_4	6.71	25.80	0.57	6.10	33.00	0.73
v_1f_5	6.09	21.50	0.47	5.21	30.70	0.67
v_1f_6	5.43	18.00	0.40	4.10	25.17	0.56
v_2f_1	4.28	20.00	0.44	4.52	30.39	0.67
v_2f_2	3.70	17.00	0.37	5.03	30.70	0.67
v_2f_3	3.61	19.00	0.42	5.35	30.54	0.68
v_2f_4	4.12	24.53	0.54	6.03	30.54	0.67
v_2f_5	3.86	21.24	0.47	4.97	30.70	0.67
v_2f_6	3.46	16.00	0.35	3.44	27.01	0.59
v_3f_1	4.68	19.30	0.42	3.88	22.56	0.49
v_3f_2	4.05	15.50	0.34	4.09	21.95	0.48
v_3f_3	4.53	17.50	0.39	5.03	26.25	0.58
v_3f_4	5.66	20.00	0.44	5.71	26.55	0.58
v_3f_5	4.80	18.40	0.40	4.82	25.17	0.55
v_3f_6	4.39	14.50	0.32	4.08	21.80	0.48
v_4f_1	4.73	21.61	0.48	3.86	21.80	0.48
v_4f_2	5.59	18.00	0.40	4.78	21.49	0.48
v_4f_3	5.19	22.33	0.49	5.70	24.10	0.53
v_4f_4	5.95	22.50	0.50	5.04	25.17	0.56
v_4f_5	5.49	20.50	0.45	5.65	24.87	0.55
v_4f_6	4.68	17.00	0.37	5.32	21.49	0.47
v_5f_1	5.29	23.44	0.52	5.60	25.48	0.57
v_5f_2	5.59	18.60	0.41	5.41	23.79	0.52
v_5f_3	6.54	20.60	0.45	4.91	27.32	0.6
v_5f_4	5.50	24.75	0.54	4.86	31.00	0.67
v_5f_5	6.35	21.10	0.46	4.89	27.17	0.59
v_5f_6	4.32	17.60	0.39	4.82	23.64	0.52
SEm(±)	0.17	0.60	0.01	0.14	0.74	0.02
CD (0.05)	0.486	1.728	0.039	0.395	2.108	0.050

of nodules per plant at flowering are presented in Table 17a and 17b.

The number of nodules produced per plant varied significantly among the varieties. In general, the number of nodules was observed to be more in the *Rabi* season compared to summer season. During summer, Sumanjana recorded greater number of nodules (21.32) and was on par with CO 6 (21.02). However, during *Rabi*, the highest number of nodules per plant was recorded in DBGV 5 (29.98).

Influence of foliar spray of nutrients and plant growth regulators was significant on number of nodules per plant at flowering. The foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded the highest number of nodules per plant at flowering during both the seasons (23.51 and 29.25 respectively). The lowest number of nodules per plant at flowering was observed in f_6 (control) during both the seasons (16.62 and 23.82 respectively).

In the case of interaction effect, the treatment combination v_1f_4 produced higher number of nodules per plant at flowering (25.80) and was on par with v_5f_4 and v_2f_4 and (24.75 and 24.53 respectively) in summer. The treatment combination v_1f_4 and v_5f_4 produced higher number of nodules per plant (33.0 and 31.0 respectively) and were comparable during *Rabi* season.

4.2.1.6 Dry Weight of Nodules per Plant

The data on variation in dry weight of nodules per plant due to varieties and foliar spray and their interaction in both the seasons is shown in Table 17a and 17b.

There was significant variation in dry weight of nodules per plant at flowering due to varieties. The variety Sumanjana recorded higher dry weight of nodule (0.47 g) and was on par with variety CO 6 (0.46 g) in summer. In the *Rabi* season, DBGV 5 and Sumanjana recorded higher nodule dry weight per plant and were on par with each other (0.66 g and 0.65 g respectively).

The dry weight of nodules per plant followed the same trend as that of number of nodules per plant. The foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) registered the highest number of nodules per plant (0.52 g and 0.64 g respectively) during both the seasons.

Among the treatment combination, v x f interactions, was significant in both the seasons. During summer season, the variety Sumanjana supplied with 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) recorded higher dry weight of nodules per plant at flowering (0.57 g) and was on par with v_2f_4 and v_5f_4 (0.54 g and 0.54 g respectively). In *Rabi* season, the highest nodule dry weight was recorded in v_1f_4 (0.73 g), followed by v_2f_3 (0.68 g).

4.2.2 Root Characters

The data on effect of varieties and foliar spray on rooting length, root volume and root dry weight at harvest of two seasons are presented in Table 18a and 18b.

It is evident from the Table 18a that, there was no significant difference in rooting length and root volume due to varieties, foliar spray and their interaction. During summer, there was no significant difference in root dry weight. However, during *Rabi*, root weight varied among the varieties and the highest root dry weight was recorded by Sumanjana (2.86 g).

Among the foliar sprays, the application of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded the highest root dry weight (2.88 g) during *Rabi*. The interaction effect on root characters was not significant in both the seasons.

Table 18a Effect of varieties and foliar application on rooting length, root volume and root dry weight during summer 2020 and *Rabi* 2020 -21

Treatments	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	Rooting length (cm)	Root volume (cm^3)	Root dry weight (g)	Rooting length (cm)	Root volume (cm^3)	Root dry weight (g)
v_1 - Sumanjana	24.66	7.70	2.33	19.03	8.42	2.86
v_2 - DBGV 5	25.01	7.80	2.36	18.69	8.26	2.76
v_3 - VBN 5	24.67	7.70	2.32	18.47	8.17	2.71
v_4 - VBN 6	24.41	7.62	2.30	18.54	8.20	2.73
v_5 - CO 6	24.08	7.51	2.27	18.57	8.21	2.74
SEm(±)	0.19	0.10	0.03	0.19	0.12	0.03
CD (0.05)	NS	NS	NS	NS	NS	0.079
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	24.76	7.73	2.33	18.48	8.17	2.72
f_2 - Foliar spray of SOP @ 0.5%	24.39	7.61	2.30	18.74	8.29	2.75
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	24.31	7.59	2.29	18.61	8.23	2.74
f_4 - f_3 + f_1	24.93	7.78	2.35	19.12	8.46	2.88
f_5 - f_3 + f_2	24.63	7.69	2.32	18.47	8.17	2.71
f_6 - Control (KAU POP)	24.38	7.61	2.30	18.53	8.19	2.74
SEm(±)	0.27	0.09	0.03	0.28	0.09	0.04
CD (0.05)	NS	NS	NS	NS	NS	0.117

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 18b. Effect of varieties and foliar application on rooting length, root volume and root dry weight during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
	Rooting length (cm)	Root volume (cm^3)	Root dry weight (g)	Rooting length (cm)	Root volume (cm^3)	Root dry weight (g)
v_1f_1	23.98	7.50	2.27	18.16	8.03	2.68
v_1f_2	24.50	7.64	2.31	19.24	8.51	2.84
v_1f_3	25.36	7.91	2.39	19.40	8.58	2.86
v_1f_4	25.00	7.80	2.36	19.32	8.55	3.15
v_1f_5	24.77	7.73	2.33	19.22	8.50	2.83
v_1f_6	24.35	7.60	2.29	18.83	8.33	2.78
v_2f_1	25.11	7.83	2.37	19.11	8.45	2.82
v_2f_2	25.70	8.02	2.42	19.19	8.49	2.83
v_2f_3	25.00	7.80	2.36	18.16	8.03	2.64
v_2f_4	24.11	7.52	2.27	19.35	8.56	2.85
v_2f_5	25.08	7.82	2.36	18.16	8.03	2.68
v_2f_6	25.06	7.82	2.36	18.16	8.03	2.72
v_3f_1	25.00	7.80	2.36	18.47	8.17	2.72
v_3f_2	25.06	7.82	2.36	18.16	8.03	2.62
v_3f_3	24.20	7.55	2.28	18.16	8.03	2.68
v_3f_4	25.60	7.99	2.41	19.24	8.51	2.84
v_3f_5	23.85	7.44	2.25	18.16	8.03	2.63
v_3f_6	24.31	7.58	2.29	18.62	8.24	2.75
v_4f_1	24.80	7.74	2.34	18.52	8.19	2.73
v_4f_2	22.75	7.10	2.14	17.87	7.90	2.64
v_4f_3	24.50	7.64	2.31	18.93	8.37	2.79
v_4f_4	25.00	7.80	2.36	18.86	8.34	2.78
v_4f_5	25.30	7.89	2.38	18.65	8.25	2.75
v_4f_6	24.14	7.53	2.27	18.44	8.15	2.72
v_5f_1	24.89	7.77	2.35	18.16	8.03	2.68
v_5f_2	23.93	7.47	2.25	19.24	8.51	2.84
v_5f_3	22.50	7.02	2.12	18.41	8.15	2.72
v_5f_4	24.92	7.78	2.35	18.83	8.33	2.78
v_5f_5	24.18	7.54	2.28	18.16	8.03	2.68
v_5f_6	24.04	7.50	2.27	18.60	8.22	2.74
SEm(±)	0.58	0.22	0.07	0.61	0.23	0.09
CD (0.05)	NS	NS	NS	NS	NS	NS

NS - Not significant

Table 19. Light intensity and photosynthetically active radiation (PAR) at monthly interval during summer 2020 and *Rabi* 2020-21

	Light intensity (klux)		PAR (µ moles s^{-1} m^{-2})	
	Summer 2020	*Rabi* 2020-21	Summer 2020	*Rabi* 2020-21
1 MAS	49.73 ± 2.69	44.73 ± 2.12	6.11 ± 0.64	5.21 ± 0.44
2 MAS	50.16 ± 2.74	48.16 ± 2.62	9.45 ± 0.16	7.25 ± 0.26
At harvest	48.1 ± 2.24	46.1 ± 2.41	5.40 ± 0.33	6.60 ± 0.23

4.2.3 Light Intensity (klux) and Photosynthetically Active Radiation (µ moles s^{-1} m^{-2}) at Monthly Interval

Table 19 represents the mean values of light intensity and PAR recorded during the cropping period (summer 2020 and *Rabi* 2020-21) at monthly interval in the coconut garden.

Light intensity was slightly higher in summer season compared to *Rabi* season. During summer season, the light intensity varied between (48.1 ± 2.24) klux to (50.16 ± 2.74) klux while it varied between (44.73 ± 2.12) klux to (48.16 ± 2.62) klux during *Rabi*. On the other hand, PAR showed marked variation in both the seasons during the entire cropping period. It increased from 1 MAS to 2 MAS and showed a decreasing trend towards harvest. The highest value of PAR was recorded at 2 MAS during both the seasons (9.45 ± 0.16 µ moles s^{-1} m^{-2} in summer and 7.25 ± 0.26 µ moles s^{-1} m^{-2} in *Rabi* season respectively).

4.2.4 Physiological Characters

The physiological characters *viz.*, crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), specific leaf weight (SLW), chlorophyll content, stomatal index, stomatal conductance and soluble protein were computed at flowering during both the seasons and presented in Table 20a to 24b.

4.2.4.1 Crop Growth Rate

The main effect and interaction effect of varieties and foliar spray on crop growth rate during both the seasons are presented in Table 20a and 20b.

Crop growth rate varied significantly due to varieties and foliar spray in both the seasons. In general, CGR increased from 30-45 DAS to 45-60 DAS thereafter it decreased between 60-75 DAS. Sumanjana recorded the highest CGR between 30-45 DAS and 45-60 DAS during both the seasons (5.74 g m^{-2} day^{-1} and 8.33 g $m^{-2}day^{-1}$ during summer season and 5.57 g m^{-2} day^{-1} and 7.22 g $m^{-2}day^{-1}$ during *Rabi* season respectively). In the summer season, between 60-75 DAS, significantly greater CGR was recorded by the variety Sumanjana (6.70 g $m^{-2}day^{-1}$). However, during *Rabi*, Sumanjana and DBGV 5 recorded higher CGR (6.09 g $m^{-2}day^{-1}$ and 6.01 g m^{-2} day^{-1}) and were on par with each other.

Foliar nutrition had significant effect on CGR and the same trend in all the growth stages during both the seasons. Between 30-45 DAS, foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded higher CGR and was on par with foliar spray

Table 20a Effect of varieties and foliar application on crop growth rate during summer 2020 and *Rabi* 2020-21, g m^{-2} day^{-1}

Treatments	Crop growth rate (CGR)					
	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	30-45 DAS	45-60 DAS	60-75 DAS	30-45 DAS	45-60 DAS	60-75 DAS
v_1 - Sumanjana	5.74	8.33	6.70	5.57	7.22	6.09
v_2 - DBGV 5	5.29	7.44	6.43	5.13	6.45	6.01
v_3 - VBN 5	5.36	6.21	4.04	5.21	5.38	3.78
v_4 - VBN 6	5.12	5.53	2.06	4.97	4.79	1.93
v_5 - CO 6	4.65	5.51	3.63	4.52	4.78	3.39
SEm(±)	0.08	0.06	0.06	0.05	0.04	0.09
CD (0.05)	0.242	0.197	0.186	0.159	0.137	0.270
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	4.91	6.48	4.28	4.76	5.61	4.01
f_2 - Foliar spray of SOP @ 0.5%	5.14	6.01	4.22	5.00	5.20	3.95
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	5.30	7.05	5.56	5.15	6.11	5.20
f_4 - f_3 + f_1	5.59	7.68	4.85	5.42	6.66	4.32
f_5 - f_3 + f_2	5.52	6.68	4.84	5.36	5.79	4.53
f_6 - Control (KAU POP)	4.94	5.72	3.67	4.80	4.96	3.44
SEm(±)	0.06	0.08	0.07	0.07	0.08	0.07
CD (0.05)	0.182	0.233	0.207	0.198	0.228	0.188

f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 20b. Interaction effect of varieties and foliar application on crop growth rate during summer 2020 and *Rabi* 2020-21, g m^{-2} day^{-1}

Treatments	CGR					
	Summer 2020			*Rabi* 2020-21		
	30-45 DAS	45-60 DAS	60-75 DAS	30-45 DAS	45-60 DAS	60-75 DAS
v_1f_1	5.76	7.50	6.28	5.59	6.50	5.87
v_1f_2	5.46	6.83	5.80	5.30	5.92	5.42
v_1f_3	5.76	8.92	6.69	5.59	7.73	6.26
v_1f_4	6.22	10.65	9.80	6.04	9.23	8.10
v_1f_5	5.69	8.60	6.53	5.52	7.46	6.11
v_1f_6	5.53	7.50	5.11	5.37	6.50	4.78
v_2f_1	5.16	7.47	6.91	5.01	6.47	6.47
v_2f_2	5.24	6.86	6.83	5.09	5.95	6.39
v_2f_3	5.00	8.44	7.70	4.85	7.32	7.20
v_2f_4	5.23	8.53	5.60	5.08	7.40	5.24
v_2f_5	5.60	7.25	6.47	5.44	6.29	6.05
v_2f_6	5.49	6.06	5.07	5.33	5.25	4.74
v_3f_1	5.19	6.22	3.05	5.04	5.39	2.86
v_3f_2	5.32	5.97	2.58	5.16	5.18	2.41
v_3f_3	5.14	6.60	6.11	4.99	5.72	5.72
v_3f_4	5.69	6.58	3.66	5.52	5.70	3.42
v_3f_5	5.55	5.62	5.53	5.39	4.87	5.17
v_3f_6	5.30	6.26	3.29	5.14	5.42	3.08
v_4f_1	4.62	5.16	1.73	4.49	4.47	1.62
v_4f_2	4.96	5.03	2.49	4.82	4.36	2.33
v_4f_3	5.46	5.80	2.43	5.30	5.02	2.27
v_4f_4	5.39	6.40	1.93	5.23	5.55	1.81
v_4f_5	5.32	5.53	2.29	5.16	4.79	2.14
v_4f_6	5.00	5.24	1.51	4.85	4.55	1.41
v_5f_1	3.80	6.04	3.45	3.69	5.24	3.22
v_5f_2	4.75	5.33	3.40	4.61	4.62	3.18
v_5f_3	5.16	5.51	4.88	5.01	4.78	4.57
v_5f_4	5.40	6.24	3.25	5.25	5.41	3.04
v_5f_5	5.44	6.40	3.38	5.28	5.55	3.16
v_5f_6	3.38	3.54	3.40	3.28	3.07	3.18
SEm(±)	0.02	0.18	0.16	0.15	0.17	0.16
CD (0.05)	0.442	0.514	0.461	0.434	0.485	0.469

of SOP (0.5%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_5) in summer and *Rabi* seasons (5.59 and 5.52 g m^{-2} day^{-1} in summer and 5.42 and 5.36 g m^{-2} day^{-1} in *Rabi* season respectively). Between 45-60 DAS, significantly higher CGR was recorded with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) in both the seasons (7.68 g $m^{-2}day^{-1}$ and 6.66 g m^{-2} day^{-1} respectively). The highest CGR was recorded with foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_3) between 60 DAS to harvest during both seasons (5.56 g $m^{-2}day^{-1}$ and 5.20 g m^{-2} day^{-1} respectively).

Regarding the interaction effect, superior CGR was recorded between 30-45 DAS, 45-60 DAS and 60-75 DAS in both the seasons in the treatment combination v_1f_4 (6.22 g m^{-2} day^{-1}, 10.65 g m^{-2} day^{-1} and 9.80 g m^{-2} day^{-1} in summer season and 6.04, 9.23 and 8.10 g m^{-2} day^{-1} in *Rabi* respectively).

4.2.4.2 Relative Growth Rate

The RGR computed between 30-45 DAS, 45-60 DAS and 60-75 DAS for both the seasons are presented in Table 21a and 21b. There was significant variation in RGR due to varieties and foliar spray during both the seasons. RGR showed a decreasing trend from initial towards harvest stages.

Between 30-45 DAS, the variety VBN 5 recorded superior RGR in both summer and *Rabi* seasons (7.33 x 10^{-2} g g^{-1} day^{-1} and 6.43 x 10^{-2} g g^{-1} day^{-1}). RGR recorded the maximum value between 45-60 DAS in both the seasons for Sumanjana (3.99 x 10^{-2} g g^{-1} day^{-1} and 3.87 x 10^{-2} g g^{-1} day^{-1}). However, between 60 DAS - harvest, RGR was the highest for DBGV 5 (2.14 x 10^{-2} g g^{-1} day^{-1}) in the summer season and VBN 5 (1.87 x 10^{-2} g g^{-1} day^{-1}) in the *Rabi* season.

There was no significant difference in RGR due to foliar spray between 30-45 DAS in both the seasons. At 45-60 DAS, higher RGR (3.95 x 10^{-2} g g^{-1} day^{-1}) was

Table 21a Effect of varieties and foliar application on relative growth rate during summer 2020 and *Rabi* 2020-21, g g^{-1} day^{-1}

Treatments	Relative growth rate (RGR) x 10^{-2}					
	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	30-45 DAS	45-60 DAS	60-75 DAS	30-45 DAS	45-60 DAS	60-75 DAS
v_1 - Sumanjana	5.68	3.99	2.05	4.98	3.87	1.53
v_2 - DBGV 5	5.43	3.85	2.14	4.76	3.73	1.55
v_3 - VBN 5	7.33	3.81	1.65	6.43	3.69	1.87
v_4 - VBN 6	6.43	3.40	0.93	5.64	3.30	1.51
v_5 - CO 6	4.96	3.22	1.52	4.35	3.12	1.67
SEm(±)	0.12	0.04	0.01	0.01	0.04	0.02
CD (0.05)	0.366	0.118	0.044	0.325	0.124	0.070
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	5.69	3.73	1.59	4.99	3.61	1.98
f_2 - Foliar spray of SOP @ 0.5%	5.88	3.44	1.61	5.15	3.34	2.07
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	5.97	3.82	1.94	5.23	3.70	1.59
f_4 - f_3 + f_1	6.14	3.95	1.56	5.38	3.82	0.89
f_5 - f_3 + f_2	6.11	3.56	1.73	5.35	3.45	1.47
f_6 - Control (KAU POP)	6.04	3.43	1.52	5.29	3.30	1.98
SEm(±)	0.15	0.05	0.02	0.13	0.04	0.02
CD (0.05)	NS	0.133	0.062	NS	0.012	0.060

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 21b. Interaction effect of varieties and foliar application on relative growth rate during summer 2020 and *Rabi* 2020-21, g g^{-1} day^{-1}

Treatments	RGR					
	Summer 2020			*Rabi* 2020-21		
	30-45 DAS	45-60 DAS	60-75 DAS	30-45 DAS	45-60 DAS	60-75 DAS
v_1f_1	5.68	3.72	2.04	4.98	3.60	1.97
v_1f_2	5.60	3.58	2.01	4.91	3.47	1.95
v_1f_3	5.63	4.22	2.01	4.94	4.09	1.94
v_1f_4	6.00	4.67	2.54	5.25	4.53	2.45
v_1f_5	5.46	3.93	1.98	4.79	3.81	1.91
v_1f_6	5.70	3.84	1.74	5.00	3.72	1.68
v_2f_1	5.44	3.95	2.31	4.76	3.82	2.23
v_2f_2	5.45	3.66	2.34	4.78	3.54	2.26
v_2f_3	5.09	4.29	2.40	4.46	4.16	2.31
v_2f_4	5.04	4.16	1.77	4.42	4.03	1.71
v_2f_5	5.53	3.65	2.13	4.84	3.54	2.06
v_2f_6	6.03	3.37	1.91	5.28	3.26	1.84
v_3f_1	7.26	3.90	1.31	6.36	3.78	1.27
v_3f_2	7.16	3.69	1.12	6.28	3.58	1.09
v_3f_3	6.88	4.02	2.33	6.03	3.89	2.25
v_3f_4	7.61	3.87	1.46	6.67	3.75	1.41
v_3f_5	7.44	3.46	2.24	6.52	3.35	2.16
v_3f_6	7.64	3.93	1.40	6.71	3.81	1.35
v_4f_1	5.75	3.32	0.82	5.04	3.21	0.79
v_4f_2	6.07	3.16	1.14	5.31	3.06	1.10
v_4f_3	6.96	3.49	1.05	6.09	3.38	1.01
v_4f_4	6.65	3.73	0.81	5.83	3.61	0.78
v_4f_5	6.53	3.34	1.01	5.72	3.23	0.97
v_4f_6	6.66	3.39	0.72	5.83	3.28	0.70
v_5f_1	4.30	3.75	1.46	3.79	3.64	1.41
v_5f_2	5.09	3.13	1.43	4.45	3.04	1.38
v_5f_3	5.28	3.07	1.89	4.64	2.97	1.82
v_5f_4	5.38	3.30	1.23	4.71	3.19	1.19
v_5f_5	5.58	3.41	1.28	4.89	3.30	1.23
v_5f_6	4.15	2.64	1.82	3.63	2.56	1.76
SEm(±)	0.32	0.10	0.05	0.28	0.10	0.05
CD (0.05)	NS	0.296	0.134	NS	0.274	0.150

NS - Not significant

recorded with the application of foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) and was on par with foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_3) in the summer season. During the *Rabi* season, significantly higher RGR between 45-60 DAS was recorded in f_4 (3.82 x 10^{-2} g g^{-1} day^{-1}). Between 60-75 DAS, the highest RGR was registered by f_3 (1.94 x 10^{-2} g g^{-1} day^{-1}) in summer season and by f_2 (2.07 x 10^{-2} g g^{-1} day^{-1}) in the *Rabi* season.

Interaction effect showed no significant variation in RGR at 30-45 DAS in both the seasons. Between 45-60 DAS and 60-75 DAS, significantly greater RGR was recorded in the treatment combination v_1f_4 in the summer season (4.67 x 10^{-2} g g^{-1} day^{-1} and 2.54 x 10^{-2} g g^{-1} day^{-1}) and in *Rabi* season, between 45-60 DAS, the v_1f_4 recorded the highest RGR (4.53 x 10^{-2} g g^{-1} day^{-1}) and between 60 DAS - harvest, the treatment combinations v_1f_4 and v_2f_3 recorded higher RGR (2.45 x 10^{-2} g g^{-1} day^{-1} and 2.31 x 10^{-2} g g^{-1} day^{-1}) and were on par with each other.

4.2.4.3 Net Assimilation Rate

The variation in NAR due to the effect of varieties and foliar spray during both the seasons are presented in Table 22a and 22b. The results revealed that NAR was significantly influenced by the varieties.

The variety DBGV 5 recorded the highest NAR between 30-45 DAS during both the seasons (1.57 x 10^{-4} and 1.54 x 10^{-4} g cm^{-2} day^{-1}). Between 45-60 DAS, the highest NAR was recorded by the variety DBGV 5 (1.49 x 10^{-4} g cm^{-2} day^{-1}) in summer season and DBGV 5 and Sumanjana recorded higher values of NAR in *Rabi* season (1.32 x 10^{-4} g cm^{-2} day^{-1} and 1.42 x 10^{-4} g cm^{-2} day^{-1}). There was significant difference in NAR between 60-75 DAS, only during summer season and the variety VBN 5 (1.53 x 10^{-4} g cm^{-2} day^{-1}) recorded higher NAR and was on par with DBGV 5 (1.44 x 10^{-4} g cm^{-2} day^{-1}) and VBN 6 (1.37 x 10^{-4} g cm^{-2} day^{-1}).

Table 22a. Effect of varieties and foliar application on net assimilation rate during summer 2020 and *Rabi* 2020-21, g cm^{-2} day^{-1}

Treatments	Net assimilation rate (NAR) x 10^{-4}					
	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	30-45 DAS	45-60 DAS	60-75 DAS	30-45 DAS	45-60 DAS	60-75 DAS
v_1 - Sumanjana	1.38	1.25	1.28	1.35	1.42	1.22
v_2 - DBGV 5	1.57	1.49	1.44	1.54	1.32	1.40
v_3 - VBN 5	1.43	0.71	1.53	1.41	0.63	1.42
v_4 - VBN 6	1.27	0.22	1.37	1.24	0.20	1.31
v_5 - CO 6	1.29	0.44	1.20	1.24	0.39	1.22
SEm(±)	0.04	0.03	0.05	0.03	0.15	0.07
CD (0.05)	0.109	0.107	0.164	0.100	0.470	NS
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	1.36	0.74	1.37	1.32	1.04	1.37
f_2 - Foliar spray of SOP @ 0.5%	1.42	0.70	1.40	1.39	0.62	1.34
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	1.36	0.94	1.54	1.34	0.83	1.46
f_4 - f_3 + f_1	1.32	0.92	1.17	1.30	0.82	1.13
f_5 - f_3 + f_2	1.39	0.85	1.25	1.35	0.75	1.18
f_6 - Control (KAU POP)	1.48	0.79	1.45	1.43	0.69	1.40
SEm(±)	0.039	0.032	0.071	0.037	0.153	0.071
CD (0.05)	NS	0.091	0.201	NS	NS	0.199

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 22b. Interaction effect of varieties and foliar application on net assimilation rate during summer 2020 and *Rabi* 2020-21, g cm^{-2} day^{-1}

Treatments	NAR x 10^{-4}					
	Summer 2020			*Rabi* 2020-21		
	30-45 DAS	45-60 DAS	60-75 DAS	30-45 DAS	45-60 DAS	60-75 DAS
v_1f_1	1.43	1.20	1.58	1.39	3.00	1.52
v_1f_2	1.65	1.05	1.40	1.61	0.93	1.33
v_1f_3	1.36	1.39	1.24	1.33	1.23	1.18
v_1f_4	1.17	1.40	1.14	1.16	1.24	1.08
v_1f_5	1.33	1.18	1.20	1.30	1.04	1.14
v_1f_6	1.33	1.26	1.13	1.29	1.11	1.07
v_2f_1	1.42	1.37	1.49	1.39	1.22	1.44
v_2f_2	1.60	1.41	1.60	1.56	1.25	1.52
v_2f_3	1.54	1.72	1.76	1.50	1.53	1.67
v_2f_4	1.48	1.59	1.22	1.45	1.40	1.16
v_2f_5	1.67	1.34	1.17	1.63	1.19	1.31
v_2f_6	1.72	1.50	1.38	1.68	1.33	1.31
v_3f_1	1.38	0.62	1.36	1.35	0.55	1.30
v_3f_2	1.51	0.61	1.34	1.48	0.54	1.28
v_3f_3	1.36	0.72	1.78	1.37	0.64	1.69
v_3f_4	1.41	0.69	1.09	1.37	0.61	1.04
v_3f_5	1.44	0.92	1.63	1.41	0.81	1.58
v_3f_6	1.50	0.69	1.97	1.47	0.61	1.63
v_4f_1	1.24	0.20	1.36	1.21	0.17	1.29
v_4f_2	1.21	0.08	1.15	1.18	0.07	1.09
v_4f_3	1.36	0.29	1.50	1.33	0.26	1.43
v_4f_4	1.24	0.29	1.33	1.22	0.26	1.27
v_4f_5	1.26	0.29	1.33	1.23	0.26	1.26
v_4f_6	1.29	0.17	1.57	1.26	0.15	1.49
v_5f_1	1.31	0.29	1.04	1.28	0.26	1.31
v_5f_2	1.15	0.34	1.51	1.11	0.30	1.47
v_5f_3	1.17	0.56	1.42	1.15	0.50	1.35
v_5f_4	1.32	0.64	1.08	1.29	0.56	1.10
v_5f_5	1.23	0.52	0.93	1.18	0.46	0.63
v_5f_6	1.54	0.31	1.20	1.46	0.28	1.48
SEm(±)	0.09	0.07	0.16	0.08	0.35	0.16
CD (0.05)	NS	NS	NS	NS	NS	NS

NS - Not significant

Regarding foliar nutrition, there was no significant difference in NAR between 30-45 DAS during both the seasons. Between 45-60 DAS, NAR varied significantly during summer season with the highest value of 0.94 x 10^{-4} g cm^{-2} day^{-1} with foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_3) and was on par with f_4 and f_5 (0.92 x 10^{-4} g cm^{-2} day^{-1} and 0.85 x 10^{-4} g cm^{-2} day^{-1} respectively). Between 60 DAS - harvest, f_3 (foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later) recorded higher NAR and was on par with f_1, f_2 and f_5 in both the seasons.

Net assimilation rate showed no significant variation during any of the growth stages due to interaction effect in both the seasons.

4.2.4.4 Specific Leaf Weight

The variation in specific leaf weight (SLW) at 30, 45, 60 DAS and harvest in both the seasons are presented in Tables 23a and 23b.

There was significant variation in SLW due to varieties and foliar spray in both the seasons. At 30 DAS, the highest value of SLW was recorded by the variety VBN 5 in both the seasons (0.43 mg cm^{-2} and 0.35 mg cm^{-2} respectively). At 45 DAS, Sumanjana recorded Superior SLW of 1.19 and 1.14 mg cm^{-2} respectively. However, at 60 DAS, both Sumanjana and DBGV 5 recorded higher values of SLW in both the seasons and were on par (2.32 mg cm^{-2} and 2.27 mg cm^{-2} in summer and 2.28 and 2.23 mg cm^{-2} in *Rabi* respectively). During both the seasons, the highest SLW was recorded by the variety Sumanjana (4.03 and 3.76 mg cm^{-2} respectively) at 75 DAS.

It is evident that foliar nutrition had significant effect on SLW at all the growth stages. At 30 DAS, foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded

Table 23a Effect of varieties and foliar application on specific leaf weight during summer 2020 and *Rabi* 2020-21, mg cm^{-2}

Treatments	Specific leaf weight (SLW)							
	Summer 2020				*Rabi* 2020-21			
Main plot - Varieties (V)	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
v_1 – Sumanjana	0.33	1.19	2.32	4.03	0.27	1.14	2.28	3.76
v_2 - DBGV 5	0.32	1.03	2.27	3.81	0.26	0.98	2.23	3.55
v_3 - VBN 5	0.43	0.59	1.55	1.13	0.35	0.56	1.52	1.05
v_4 - VBN 6	0.19	0.58	0.83	0.72	0.16	0.56	0.81	0.67
v_5 - CO 6	0.33	0.68	1.30	1.33	0.26	0.62	1.28	1.24
SEm(±)	0.03	0.01	0.02	0.03	0.02	0.01	0.02	0.02
CD (0.05)	0.080	0.041	0.061	0.091	0.067	0.031	0.056	0.072
Sub plot - Foliar spray (F)								
f_1 - Foliar spray of 19:19:19 @ 1%	0.30	0.76	1.46	1.87	0.25	0.73	1.43	1.75
f_2 - Foliar spray of SOP @ 0.5%	0.28	0.88	1.49	1.67	0.22	0.85	1.47	1.56
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	0.36	0.81	1.83	2.55	0.29	0.77	1.80	2.37
f_4 - f_3 + f_1	0.37	0.93	1.65	3.00	0.30	0.89	1.62	2.80
f_5 - f_3 + f_2	0.35	0.84	1.79	2.51	0.29	0.81	1.76	2.34
f_6 - Control (KAU POP)	0.27	0.66	1.70	1.60	0.21	0.59	1.67	1.50
SEm(±)	0.03	0.01	0.02	0.04	0.02	0.01	0.02	0.03
CD (0.05)	0.083	0.033	0.052	0.114	0.066	0.029	0.070	0.084

f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 23b. Interaction effect of varieties and foliar application on specific leaf weight during summer 2020 and *Rabi* 2020-21, mg cm^{-2}

Treatments	SLW							
	Summer 2020				*Rabi* 2020-21			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
v_1f_1	0.34	1.15	2.25	3.79	0.28	1.10	2.21	3.53
v_1f_2	0.28	1.18	2.20	3.26	0.22	1.13	2.16	3.04
v_1f_3	0.33	1.15	2.34	4.10	0.27	1.11	2.30	3.82
v_1f_4	0.31	1.53	2.62	5.22	0.25	1.47	2.57	4.87
v_1f_5	0.46	1.19	2.40	4.12	0.37	1.14	2.36	3.84
v_1f_6	0.26	0.94	2.13	3.68	0.21	0.90	2.09	3.43
v_2f_1	0.26	1.06	2.09	3.59	0.21	1.02	2.05	3.34
v_2f_2	0.30	1.28	2.35	3.51	0.25	1.23	2.30	3.27
v_2f_3	0.41	0.93	2.39	4.33	0.34	0.89	2.35	4.03
v_2f_4	0.44	1.00	2.09	4.47	0.36	0.96	2.06	4.17
v_2f_5	0.40	0.97	2.38	4.01	0.33	0.93	2.34	3.74
v_2f_6	0.09	0.92	2.33	2.95	0.07	0.88	2.29	2.75
v_3f_1	0.47	0.51	1.20	0.75	0.38	0.49	1.18	0.70
v_3f_2	0.40	0.68	1.19	0.65	0.32	0.66	1.17	0.61
v_3f_3	0.37	0.58	1.72	1.32	0.30	0.56	1.69	1.23
v_3f_4	0.48	0.57	1.17	1.91	0.39	0.54	1.15	1.78
v_3f_5	0.42	0.63	2.10	1.59	0.34	0.61	2.07	1.48
v_3f_6	0.43	0.53	1.89	0.53	0.35	0.51	1.85	0.50
v_4f_1	0.09	0.56	0.67	0.48	0.08	0.54	0.66	0.45
v_4f_2	0.11	0.56	0.43	0.35	0.09	0.54	0.43	0.32
v_4f_3	0.29	0.64	1.09	1.00	0.24	0.61	1.07	0.93
v_4f_4	0.20	0.58	0.98	1.19	0.16	0.56	0.96	1.11
v_4f_5	0.17	0.63	0.97	1.04	0.14	0.60	0.95	0.97
v_4f_6	0.30	0.54	0.82	0.26	0.25	0.52	0.81	0.25
v_5f_1	0.35	0.50	1.08	0.75	0.28	0.48	1.06	0.70
v_5f_2	0.30	0.72	1.31	0.61	0.24	0.69	1.28	0.57
v_5f_3	0.38	0.73	1.59	1.99	0.31	0.70	1.56	1.85
v_5f_4	0.41	0.96	1.37	2.23	0.33	0.93	1.35	2.08
v_5f_5	0.31	0.80	1.11	1.80	0.25	0.77	1.09	1.68
v_5f_6	0.24	0.37	1.35	0.59	0.15	0.15	1.33	0.55
SEm(±)	0.07	0.03	0.04	0.09	0.05	0.02	0.05	0.07
05)	NS	0.079	0.121	0.250	NS	0.068	0.154	0.187

NS - Not significant

higher SLW (0.37 mg cm^{-2} in summer and 0.30 mg cm^{-2} in *Rabi*) at 30 DAS and was on par with f_3, f_5 and f_1 in both the seasons. The highest SLW was recorded in f_4 at 45 DAS in both the seasons (0.93 mg cm^{-2} and 0.89 mg cm^{-2} respectively). At 60 DAS, the highest SLW (1.83 mg cm^{-2}) was recorded in f_3 in summer season and the treatments f_3 and f_5 were on par in *Rabi* season (1.80 and 1.76 mg cm^{-2} respectively). At 75 DAS, maximum SLW of 3 and 2.8 mg cm^{-2} was recorded by f_4 in the summer and *Rabi* respectively and was superior to rest of the treatments.

The interaction between varieties and foliar application marked no significant variation in SLW at 30 DAS during both the seasons. At 45, 60 and 75 DAS, the highest SLW was recorded in the treatment combination v_1f_4 in summer (1.53 mg cm^{-2}, 2.62 mg cm^{-2} and 5.22 mg cm^{-2}) and *Rabi* season (1.47 mg cm^{-2}, 2.57 mg cm^{-2} and 4.87 mg cm^{-2} respectively).

4.2.4.5 Chlorophyll Content

The variation in chlorophyll content at flowering due to varieties, and foliar spray and their interaction during both the seasons is given in Table 24a and 24b.

The results revealed that the chlorophyll content varied significantly among the varieties during both the seasons. During summer, the highest chlorophyll content was recorded by the variety DBGV 5 (1.96 mg g^{-1} fresh tissue) while during *Rabi*, Sumanjana recorded the same (2.36 mg g^{-1} fresh tissue).

Foliar spray had significant effect on chlorophyll content at flowering during both the seasons. The foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded higher chlorophyll content (1.88 mg g^{-1} fresh tissue) and was on par with f_3, f_5 and f_1 in summer season and the highest value by the subplot treatment f_4 (2.25 mg g^{-1} fresh tissue) in *Rabi* season.

Varieties and foliar nutrition together had significant effect on chlorophyll content and the highest chlorophyll content was recorded by v_1f_4 during both the seasons, the values being 2.15 mg g^{-1} fresh tissue and 2.58 mg g^{-1} fresh tissue respectively.

4.2.4.6 Stomatal Index

The stomatal index computed at flowering are presented in Table 24a and 24b. There was significant variation in stomatal index due to varieties, foliar spray and their interaction.

Among the varieties, Sumanjana recorded the lowest stomatal index in both the seasons (15.16% and 13.34%). The highest value of stomatal index was recorded by the variety VBN 6 (20.75%) in summer season and the varieties VBN 6 and CO 6 recorded higher value of stomatal index (16.40% and 16.07 %) in *Rabi* and were on par.

Foliar nutrition and PGRs had significant influence on stomatal index and spray of 19:19:19 (1%) at 45 and 60 DAS + NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded lower stomatal index (17.70 %) and was on par with rest of the treatments except f_2, in summer season. During *Rabi*, there was no significant difference in stomatal index due to foliar spray.

There was significant difference in stomatal index due to interaction of varieties and foliar spray in summer season and the lower stomatal index was recorded in v_1f_4 (13.80 %) and was on par with v_1f_3 (14.0%) and v_1f_5 (14.20 %).

4.2.4.7 Stomatal Conductance

The effect of varieties, foliar spray and their interaction on stomatal conductance at flowering are presented in Table 24a and 24b.

Table 24a Effect of varieties and foliar application on chlorophyll content, stomatal index, stomatal conductance and soluble protein at flowering during summer 2020 and *Rabi* 2020-21

Treatment	Summer 2020				*Rabi* 2020-21			
	Chlorophyll content (mg g^{-1})	Stomatal index (%)	Stomatal conductance (m moles m^{-2} s^{-1})	Soluble protein (mg g^{-1})	Chlorophyll content (mg g^{-1})	Stomatal index (%)	Stomatal conductance (m moles m^{-2} s^{-1})	Soluble protein (mg g^{-1})
Main plot - Varieties (V)								
v_1 - Sumanjana	1.91	15.16	30.22	17.66	2.36	13.34	28.34	17.17
v_2 - DBGV 5	1.96	16.81	29.04	17.91	2.27	14.98	21.86	16.86
v_3 - VBN 5	1.57	17.21	24.04	17.66	1.88	15.34	24.58	16.66
v_4 - VBN 6	1.51	20.75	23.07	17.48	1.82	16.40	26.06	16.73
v_5 - CO 6	1.70	18.89	26.05	17.24	2.04	16.07	27.5	16.75
SEm(±)	0.02	0.20	0.38	0.20	0.06	0.33	0.21	0.25
CD (0.05)	0.048	0.857	1.011	NS	0.021	1.035	0.653	NS
Sub plot - Foliar spray (F)								
f_1 - Foliar spray of 19:19:19 @ 1%	1.70	17.91	25.99	17.73	2.03	14.93	25.15	16.67
f_2 - Foliar spray of SOP @ 0.5%	1.62	18.52	24.84	17.46	1.94	15.18	24.36	16.91
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	1.80	18.16	27.68	17.41	2.17	15.63	24.95	16.79
f_4 - f_3 + f_1	1.88	17.70	28.84	17.85	2.25	15.61	29.46	17.25
f_5 - f_3 + f_2	1.81	18.04	27.72	17.64	2.17	15.26	26.69	16.66
f_6 - Control (KAU POP)	1.55	17.96	23.83	17.46	1.89	14.76	23.38	16.71
SEm(±)	0.23	0.21	0.33	0.25	0.028	0.31	0.33	0.510
CD (0.05)	0.064	0.600	0.920	NS	0.078	NS	0.945	NS

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 24a Interaction effect of varieties and foliar application on chlorophyll content, stomatal index, stomatal conductance and soluble protein at flowering during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020				*Rabi* 2020-21			
	Chlorophyll content (mg g^{-1})	Stomatal index (%)	Stomatal conductance (m moles m^{-2} s^{-1})	Soluble protein (mg g^{-1})	Chlorophyll content (mg g^{-1})	Stomatal index (%)	Stomatal conductance (m moles m^{-2} s^{-1})	Soluble protein (mg g^{-1})
v_1f_1	1.96	16.00	30.00	17.17	2.35	13.63	26.18	16.38
v_1f_2	1.74	16.80	30.34	17.54	2.37	14.89	22.51	17.36
v_1f_3	1.97	14.00	30.26	18.16	2.37	12.41	26.44	17.50
v_1f_4	2.15	13.80	33.00	17.90	2.58	12.23	35.20	17.43
v_1f_5	2.00	14.20	30.71	17.73	2.40	12.58	31.21	17.34
v_1f_6	1.64	16.15	27.00	17.44	2.11	14.31	28.49	16.99
v_2f_1	1.98	15.85	30.46	17.98	2.38	14.04	22.46	17.24
v_2f_2	2.00	16.35	26.70	18.40	2.09	14.49	19.41	17.31
v_2f_3	1.99	17.85	30.61	17.90	2.39	15.82	18.94	16.38
v_2f_4	1.99	18.05	30.61	17.26	2.39	15.99	31.95	17.45
v_2f_5	2.00	17.65	30.71	17.95	2.40	15.64	20.25	16.38
v_2f_6	1.76	15.11	25.12	17.94	1.96	13.91	18.15	16.38
v_3f_1	1.47	16.25	22.53	17.90	1.76	14.40	24.55	16.66
v_3f_2	1.43	16.75	21.92	17.95	1.71	14.84	21.25	16.38
v_3f_3	1.71	18.25	26.19	17.33	2.05	16.17	23.77	16.38
v_3f_4	1.73	18.45	26.54	18.33	2.07	16.35	29.69	17.36
v_3f_5	1.64	18.05	25.22	17.08	1.97	15.99	25.18	16.38
v_3f_6	1.42	15.11	21.82	17.40	1.71	14.27	23.03	16.80
v_4f_1	1.42	19.75	21.49	17.76	1.68	16.89	24.81	16.70
v_4f_2	1.40	21.95	21.46	16.29	1.68	16.24	29.33	16.12
v_4f_3	1.57	20.25	24.05	17.54	1.88	16.95	27.23	17.08
v_4f_4	1.64	21.95	25.12	17.90	1.96	16.53	21.61	17.01
v_4f_5	1.62	21.75	24.81	18.12	1.94	15.46	28.80	16.82
v_4f_6	1.40	21.55	21.51	17.28	1.80	16.37	24.55	16.63
v_5f_1	1.66	19.27	25.48	17.82	1.99	15.66	27.75	16.38
v_5f_2	1.55	17.45	23.75	17.13	1.86	15.46	29.33	17.36
v_5f_3	1.78	18.95	27.31	16.11	2.14	16.79	28.40	16.61
v_5f_4	1.89	18.46	28.93	17.84	2.26	16.97	28.85	16.99
v_5f_5	1.77	18.75	27.15	17.31	2.12	16.61	28.00	16.38
v_5f_6	1.54	20.25	23.70	17.21	1.85	14.92	22.67	16.77
SEm(±)	0.05	0.52	0.74	0.55	0.06	0.73	0.72	0.51
CD (0.05)	0.140	1.493	2.132	NS	0.171	NS	2.036	NS

NS - Not significant

The varieties and foliar nutrition tested had significant effect on stomatal conductance during both the seasons. Sumanjana recorded the highest stomatal conductance at flowering (30.22 m moles m^{-2} s^{-1} and 28.34 m moles m^{-2} s^{-1} respectively) during both the seasons.

Foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) registered significantly higher stomatal conductance during both the seasons (28.84 m moles m^{-2} s^{-1} and 29.46 m moles m^{-2} s^{-1} respectively).

Among the interactions, stomatal conductance was superior with v_1f_4 recording the highest during both the seasons, the values being 33.0 m moles m^{-2} s^{-1} and 35.20 m moles m^{-2} s^{-1} respectively.

4.2.4.8 Soluble Protein

The data on effect of varieties, foliar spray and their interaction on soluble protein are presented in Tables 24a and 24b.

Perusal of the data in Tables 24a and 24b indicated no significant variation in soluble protein content at flowering during both the seasons.

4.2.5 Yield Attributes and Yield

Yield attributes *viz.*, days to 50 per cent flowering, number of pods per plant, number of seeds per pod, 100 seed weight, seed and haulm yield per plant were recorded at harvest and the seed yield and haulm yield per ha, total dry matter production and harvest index were computed and presented in Tables 25a to 27b.

4.2.5.1 Days to 50 Per Cent Flowering

The influence of main plot factor, subplot factor and their interaction effects on days to 50 per cent flowering is given in Tables 25a and 25b. There was significant variation in days to 50 per cent flowering due to varieties and foliar spray in both seasons.

In general, the plants grown in summer season flowered earlier than *Rabi*. The number of days taken for 50 per cent flowering varied significantly among the varieties. During summer, the time taken for 50 per cent flowering ranged from 34.29 days to 41.85 days while during *Rabi,* it ranged between 37.84 days to 46.55 days. Sumanjana attained 50 per cent flowering earlier compared to the other varieties in both seasons (34.29 days and 37.84 days respectively). Among the varieties, VBN 6 and VBN 5 took more time to flower during summer (41.85 days and 41.37 days) and *Rabi* (46.55 and 46.25).

Foliar spraying of nutrients and PGR elicited significant variation in days to 50 per cent flowering. The subplot factor, foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_3) resulted in early flowering (36.58 days) and was on par with f_5 (37.02 days) in summer. During the *Rabi*, the treatments, f_3 took lesser days (40.63 days) to attain 50 per cent flowering and was on par with f_4 (41.71 days) and f_5 (41.03 days). Flowering was found to be significantly delayed in foliar spray with nutrients alone *viz.*, f_2 (39.89 days), f_6 (39.35 days) and f_1 (39.31 days) and were on par with each other during summer. The same trend was observed during *Rabi* with 44.15, 43.87 and 43.51 days taken by f_2, f_6 and f_1 respectively.

Among the interactions, Sumanjana with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) recorded the shortest duration to reach 50 per cent flowering during both the seasons (31.15 days and 34.48 days respectively).

Table 25a. Effect of varieties and foliar application on days to 50 per cent flowering, number of pods per plant and number of seeds per pod during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
Main plot - Varieties (V)	Days to 50 % flowering	Number of pods per plant	Number of seeds per pod	Days to 50% flowering	Number of pods per plant	Number of seeds per pod
v_1 - Sumanjana	34.29	27.30	7.34	37.84	26.54	7.16
v_2 - DBGV 5	36.54	26.04	7.21	40.49	25.28	7.26
v_3 - VBN 5	41.37	19.82	7.12	46.25	19.27	7.16
v_4 - VBN 6	41.85	19.10	7.15	46.55	18.57	7.09
v_5 - CO 6	37.48	21.97	7.16	41.28	21.36	6.99
SEm(±)	0.89	0.30	0.08	0.72	0.22	0.06
CD (0.05)	0.289	0.940	NS	2.236	0.691	NS
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	39.31	22.47	7.13	43.51	21.85	7.19
f_2 - Foliar spray of SOP @ 0.5%	39.89	20.95	7.23	44.15	20.37	7.08
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	36.58	23.97	7.18	40.63	23.31	7.06
f_4 - f_3 + f_1	37.68	25.02	7.37	41.71	24.27	7.24
f_5 - f_3 + f_2	37.02	23.50	7.12	41.03	22.85	7.15
f_6 - Control (KAU POP)	39.35	21.17	7.14	43.87	20.58	7.08
SEm(±)	0.29	0.29	0.09	0.54	0.32	0.09
CD (0.05)	0.829	0.812	NS	1.513	0.891	NS

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 25b. Interaction effect of varieties and foliar application on days to 50 per cent flowering, number of pods per plant and number of seeds per pod during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
	Days to 50% flowering	Number of pods per plant	Number of seeds per pod	Days to 50% flowering	Number of pods per plant	Number of seeds per pod
v_1f_1	35.40	28.09	7.00	39.18	27.31	6.96
v_1f_2	36.38	25.32	7.42	40.27	24.61	7.11
v_1f_3	31.15	27.30	7.48	34.48	26.54	7.36
v_1f_4	34.20	30.24	7.45	37.86	29.40	7.26
v_1f_5	33.40	28.17	7.41	36.97	27.39	7.19
v_1f_6	35.20	24.69	7.26	38.31	24.00	7.07
v_2f_1	36.26	25.32	7.37	40.14	24.61	7.29
v_2f_2	38.00	25.16	7.40	42.07	24.46	7.46
v_2f_3	35.70	27.22	7.00	39.52	26.46	7.26
v_2f_4	36.00	28.30	7.46	39.85	27.26	7.00
v_2f_5	35.63	23.85	7.00	39.70	23.19	7.28
v_2f_6	37.63	26.43	7.00	41.65	25.70	7.27
v_3f_1	41.72	18.36	7.12	46.18	17.85	7.26
v_3f_2	44.00	18.06	7.00	48.71	17.55	7.28
v_3f_3	39.55	22.31	7.00	43.78	21.70	7.03
v_3f_4	40.77	21.36	7.42	45.13	20.77	7.43
v_3f_5	38.77	21.35	7.00	42.92	20.76	6.92
v_3f_6	43.41	17.50	7.18	50.78	17.02	7.05
v_4f_1	45.26	18.72	7.14	50.10	18.20	7.20
v_4f_2	41.10	17.25	6.89	45.50	16.77	6.60
v_4f_3	40.31	19.62	7.30	44.62	19.08	7.11
v_4f_4	40.93	20.76	7.27	45.31	20.19	7.26
v_4f_5	40.70	20.57	7.19	45.05	20.00	7.35
v_4f_6	42.79	17.66	7.11	48.75	17.17	7.01
v_5f_1	37.90	21.87	7.00	41.95	21.26	7.22
v_5f_2	39.95	18.99	7.42	44.22	18.46	6.95
v_5f_3	36.20	23.40	7.10	40.75	22.75	6.53
v_5f_4	36.50	24.43	7.26	40.40	23.75	7.23
v_5f_5	36.60	23.56	7.00	40.51	22.90	7.02
v_5f_6	37.70	19.59	7.17	39.86	19.05	6.98
SEm(±)	0.67	0.66	0.21	1.31	0.68	0.19
CD (0.05)	1.911	1.905.	NS	3.809	1.945	NS

NS - Not significant

4.2.5.2 Number of Pods per Plant

The variations in number of pods per plant due to the treatments are presented in Table 25a and 25b. There was significant variation in number of pods per plant due to varieties and foliar spray and their interaction in both the seasons. Individual effect of varieties and foliar spray on number of pods per plant was significant and was superior for Sumanjana (27.30 and 26.54) during both the seasons.

Superior number of pods per plant were recorded with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) during both the seasons (25.02 and 24.27 respectively).

The interaction between varieties and foliar application recorded significant variation in number of pods per plant. Sumanjana along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) recorded the highest number of pods per plant in both the seasons (30.24 and 29.40 respectively). This was followed by v_2f_4 having 28.30 and 27.26 pods per plant during both seasons.

4.2.5.3 Number of Seeds per Pod

The data on the effect of varieties, foliar spray and their interaction on number of seeds per pods due to varieties are represented in Tables 25a and 25b.

Perusal of data in Tables 25a and 25b revealed that, there was no significant variation in number of seeds per pod due to varieties, foliar spray and their interaction effect.

4.2.5.4 Hundred Seed Weight

The data on hundred seed weight as influenced by varieties, foliar spray and their interaction for both the seasons are presented in Tables 26a and 26b.

Hundred seed weight was significantly influenced by all the main factors. The varieties, DBGV 5 and Sumanjana produced bold seeds with higher 100 seed weight and were on par with each other in both the seasons (5.01 g and 4.99 g during summer and 4.88 g and 4.92 g during *Rabi* respectively).

Foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in higher value of 100 seed weight in summer and *Rabi* seasons (4.72 g and 4.66 g respectively) and was on par with f_1 (4.63 g and 4.57 g).

The results showed that interaction had significant effect on hundred seed weight. Sumanjana along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) recorded higher seed weight (5.30 g) and was on par with v_1f_5 (5.17 g) and v_2f_4 (5.27 g) in the first season. In *Rabi*, the treatment combinations v_1f_4 (6.17 g) and v_2f_4 (5.78 g) were at par with each other.

4.2.5.5 Seed Yield per Plant

The variation in seed yield per plant due to varieties and foliar spray during both the seasons are presented in Tables 26a and 26b.

The study revealed that varieties and foliar fertilization exerted significant influence on seed yield per plant in blackgram. The influence of the main factors were significant during both the seasons. Sumanjana recorded higher seed yield per plant in both the seasons (5.83 g and 5.56 g) and was on par with DBGV 5 (5.80 g and 5.44 g) in summer and *Rabi* respectively.

Foliar spray given significantly influenced the seed yield per plant and spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) produced the highest seed yield per plant in both the seasons (5.71 g and 5.35 g per plant respectively).

Regarding the interaction effect, higher seed yield per plant was realized in Sumanjana along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) and was on par with DBGV 5 with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_2f_4) in summer season (6.42 g and 6.26 g respectively). During *Rabi*, higher seed yield per plant was recorded by v_1f_4 and was on par with v_2f_1 (6.17 g and 5.78 g).

4.2.5.6 Haulm Yield per Plant

The data on haulm yield per plant as influenced by varieties, foliar spray and their interaction are given in Tables 26a and b.

There was significant variation in haulm yield per plant among the varieties during both the seasons. The variety DBGV 5 recorded higher haulm yield per plant and was on par with Sumanjana in the first season (13.20 g and 13.12 g). The haulm yields were comparable during *Rabi* season also, with 12.82 and 12.95 g per plant for DBGV 5 and Sumanjana respectively.

There was significant difference in haulm yield per plant due to foliar spray. The highest haulm yield per plant was recorded with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) in both the seasons (12.37 g and 12.42 g respectively). Haulm yield recorded was lower for control (f_6) in summer and *Rabi* (10.37 g and 10.36 g respectively).

Regarding the interaction effect, v_1f_4 recorded higher haulm yield per plant and was on par with v_2f_4 during both the seasons (14.57 and 14.46 g in summer and 15.11 g and 14.27 g in the *Rabi* respectively).

Table 26a Effect of varieties and foliar application on 100 seed weight, seed yield and haulm yield per plant during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
	100 seed weight	Seed yield per plant	Haulm yield per plant	100 seed weight	Seed yield per plant	Haulm yield per plant
Main plot - Varieties (V)						
v_1 - Sumanjana	4.99	5.83	13.12	4.88	5.56	12.95
v_2 - DBGV 5	5.01	5.80	13.20	4.92	5.44	12.82
v_3 - VBN 5	4.15	4.74	10.56	4.10	4.58	10.51
v_4 - VBN 6	4.30	4.52	9.31	4.25	4.39	9.25
v_5 - CO 6	4.30	5.12	10.60	4.39	4.57	10.36
SEm(±)	0.04	0.02	0.12	0.06	0.07	0.17
CD (0.05)	0.136	0.066	0.372	0.172	0.208	0.519
Subplot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	4.63	5.09	10.87	4.57	4.91	10.71
f_2 - Foliar spray of SOP @ 0.5%	4.55	4.79	11.06	4.49	4.49	10.78
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	4.50	5.40	11.84	4.43	5.04	11.52
f_4 - $f_3 + f_1$	4.72	5.71	12.37	4.66	5.35	12.42
f_5 - $f_3 + f_2$	4.57	5.43	11.63	4.46	5.08	11.29
f_6 - Control (KAU POP)	4.33	4.78	10.37	4.45	4.57	10.36
SEm(±)	0.05	0.04	0.15	0.05	0.07	0.15
CD (0.05)	0.129	0.099	0.431	0.143	0.198	0.436

f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 26b. Interaction effect of varieties and foliar application on 100 seed weight, seed yield and haulm yield per plant during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
	100 seed weight	Seed yield per plant	Haulm yield per plant	100 seed weight	Seed yield per plant	Haulm yield per plant
v_1f_1	4.88	5.88	13.48	4.82	5.63	12.75
v_1f_2	4.95	5.30	12.85	4.89	4.98	12.88
v_1f_3	4.98	5.82	13.24	4.92	5.51	12.77
v_1f_4	5.30	6.42	14.57	5.24	6.17	15.11
v_1f_5	5.17	6.12	12.71	4.85	5.50	12.05
v_1f_6	4.64	5.45	11.87	4.59	5.56	12.12
v_2f_1	4.95	5.87	13.01	4.89	5.78	12.79
v_2f_2	4.98	5.48	13.48	4.85	5.32	12.84
v_2f_3	4.97	5.98	13.33	4.84	5.64	12.57
v_2f_4	5.27	6.26	14.46	5.21	5.65	14.27
v_2f_5	4.97	6.03	13.49	4.85	5.46	12.97
v_2f_6	4.95	5.18	11.41	4.86	4.77	11.51
v_3f_1	4.45	4.50	9.93	4.40	4.45	10.02
v_3f_2	4.30	4.36	9.99	4.25	4.28	10.04
v_3f_3	4.01	5.15	11.49	3.96	5.18	11.20
v_3f_4	4.06	5.24	11.66	4.01	4.98	11.63
v_3f_5	4.10	4.87	10.55	4.05	4.63	10.50
v_3f_6	4.00	4.34	9.77	3.95	3.96	9.68
v_4f_1	4.12	4.21	8.35	4.07	4.25	8.47
v_4f_2	4.05	4.18	9.32	4.00	4.00	8.60
v_4f_3	4.44	4.68	10.33	4.39	4.10	9.78
v_4f_4	4.60	4.93	9.56	4.55	5.01	9.84
v_4f_5	4.55	4.80	10.35	4.50	4.71	10.10
v_4f_6	4.06	4.29	7.94	4.01	4.29	8.70
v_5f_1	4.74	5.01	9.56	4.69	4.44	9.50
v_5f_2	4.48	4.64	9.64	4.43	3.88	9.52
v_5f_3	4.12	5.36	10.81	4.07	4.77	11.27
v_5f_4	4.36	5.70	11.61	4.31	4.96	11.27
v_5f_5	4.09	5.33	11.07	4.04	5.12	10.84
v_5f_6	4.88	4.64	10.89	4.82	4.27	9.78
SEm(±)	0.10	0.07	0.33	0.12	0.16	0.36
CD (0.05)	0.297	0.212	0.955	0.338	0.454	1.029

4.2.5.7 Seed Yield

The data on seed yield (kg ha^{-1}) as influenced by varieties, foliar spray and their interaction are presented in Tables 27a and 27b. There was significant variation in seed yield ha^{-1} during both the seasons.

The varieties tested were found to vary significantly with respect to seed yield ha^{-1}. Among these, Sumanjana recorded higher seed yield ha^{-1} and was on par with DBGV 5 during both the seasons (1530 kg ha^{-1} and 1501 kg ha^{-1} in summer and 1447 kg ha^{-1} and 1446 kg ha^{-1} in *Rabi* respectively). The lowest of seed yield was recorded by VBN 6 during both seasons (1203 kg ha^{-1} and 1176 kg ha^{-1} in summer and *Rabi* respectively).

There was significant difference in seed yield ha^{-1} due to foliar spray during both the seasons. Foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) registered the highest seed yield in both the seasons (1536 kg ha^{-1} and 1474 kg ha^{-1} respectively). The lowest seed yield was recorded in control (f_6) with the values being 1231 kg ha^{-1} and 1182 kg ha^{-1} during summer *Rabi* respectively.

Among the interactions, higher seed yield ha^{-1} was recorded in Sumanjana with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) and was on par with DBGV 5 with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_2f_4) in the summer season (1750 kg ha^{-1} and 1713 kg ha^{-1}). During *Rabi* season, the highest seed yield was recorded in v_1f_4 (1700 kg ha^{-1}).

Pooled analysis of seed yield revealed that, the varieties Sumanjana and DBGV 5 recorded higher seed yield (1489 kg ha^{-1} and 1473 kg ha^{-1}) and subplot factor f_4 recorded the highest seed yield (1505 kg ha^{-1}). The effect of main plot and subplot factors was reflected in interaction and the treatment combination v_1f_4 (1725 kg ha^{-1}) recorded the highest seed yield.

4.2.5.8 Haulm Yield

The data on effect of varieties, foliar spray and their interaction on haulm yield (kg ha^{-1}) are given in Tables 27a and 27b. Haulm yield varied significantly due to treatments during both the seasons.

The variation in haulm yield ha^{-1} was significant among the varieties during both the seasons. The variety DBGV 5 (3534 kg ha^{-1} and 3440 kg ha^{-1}) recorded higher haulm yield and was on par with Sumanjana (3513 and 3472 kg ha^{-1}) in summer and *Rabi* season. This was followed by CO 6 (2841 kg ha^{-1}) during summer season and VBN 5 (2823 kg ha^{-1}) during *Rabi*.

The results revealed that haulm yield varied significantly with foliar spray. Among the various subplot treatments, foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded the highest haulm yield (3314 kg ha^{-1} and 3313 kg ha^{-1}).

In the case of interaction, the treatment combination v_1f_4 and v_2f_4 recorded higher values for haulm yield kg ha^{-1} and were on par with each other during both the seasons (3900 kg ha^{-1} and 3870 kg ha^{-1} in summer and 4048 kg ha^{-1} and 3827 kg ha^{-1} in *Rabi* season respectively).

4.2.5.9 Total Dry Matter Production

The data on effect of varieties and foliar spray on dry matter production on both the seasons are presented in Tables 27a and 27b. There was significant variation in TDMP due to treatments.

The variety Sumanjana recorded higher TDMP and was on par with DBGV 5

Table 27a. Effect of varieties and foliar application on seed yield, haulm yield, TDMP and harvest index during summer 2020 and *Rabi* 2020-21

Treatment	Summer 2020				*Rabi* 2020-21				Pooled mean seed yield (kg ha^{-1})
	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	TDMP (kg ha^{-1})	Harvest index	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	TDMP (kg ha^{-1})	Harvest index	
Main plot - Varieties (V)									
v_1 - Sumanjana	1530	3513	5028	0.30	1447	3472	4900	0.29	1489
v_2 - DBGV 5	1501	3534	5020	0.30	1446	3440	4865	0.30	1473
v_3 - VBN 5	1259	2832	4076	0.31	1230	2823	4033	0.30	1244
v_4 - VBN 6	1203	2497	3685	0.33	1176	2486	3642	0.32	1189
v_5 - CO 6	1367	2841	4192	0.33	1314	2783	4077	0.32	1341
SEm(±)	13.8	32.2	35.9	0.01	22.3	44.9	39.82	0.01	12.9
CD (0.05)	42.44	99.24	110.79	NS	68.76	138.50	122.710	NS	37.29
Sub plot - Foliar spray (F)									
f_1 - Foliar spray of 19:19:19 @ 1%	1319	2913	4216	0.31	1279.77	2855	4135	0.31	1299
f_2 - Foliar spray of SOP @ 0.5%	1288	2963	4236	0.31	1246.81	2873	4120	0.30	1267
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	1419	3172	4576	0.31	1365.95	3071	4437	0.31	1392
f_4 - f_3 + f_1	1536	3314	4835	0.32	1473.51	3313	4786	0.31	1505
f_5 - f_3 + f_2	1439	3117	4542	0.32	1387.43	3011	4399	0.31	1413
f_6 - Control (KAU POP)	1230	2781	3997	0.31	1181.88	2762	3944	0.30	1206
SEm(±)	18.8	40.8	44.4	0.01	18.36	41.3	47.6	0.04	13.0
CD (0.05)	52.96	99.24	125.15	NS	51.728	116.24	133.99	NS	36.30

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 27b. Interaction effect of varieties and foliar application on seed yield, haulm yield, TDMP and harvest index during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020				*Rabi* 2020-21				Pooled mean seed yield (kg ha^{-1})
	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	TDMP (kg ha^{-1})	Harvest index	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	TDMP (kg ha^{-1})	Harvest index	
v_1f_1	1474	3609	5068	0.29	1402	3421	4803	0.29	1438
v_1f_2	1399	3442	4826	0.29	1379	3456	4815	0.29	1389
v_1f_3	1525	3545	5055	0.30	1414	3425	4820	0.29	1470
v_1f_4	1750	3900	5635	0.31	1700	4048	5728	0.30	1725
v_1f_5	1618	3403	5006	0.32	1507	3234	4720	0.32	1562
v_1f_6	1415	3181	4581	0.31	1282	3251	4513	0.28	1348
v_2f_1	1503	3485	4973	0.30	1427	3430	4837	0.29	1465
v_2f_2	1447	3609	5042	0.29	1426	3423	4849	0.29	1437
v_2f_3	1525	3570	5080	0.30	1488	3373	4841	0.31	1507
v_2f_4	1713	3870	5569	0.31	1538	3827	5345	0.29	1626
v_2f_5	1539	3613	5137	0.30	1527	3478	4985	0.30	1533
v_2f_6	1278	3056	4319	0.29	1266	3090	4336	0.29	1272
v_3f_1	1181	2662	3829	0.31	1171	2693	3844	0.30	1176
v_3f_2	1149	2679	3814	0.30	1134	2697	3812	0.30	1142
v_3f_3	1373	3078	4436	0.31	1315	3007	4302	0.30	1344
v_3f_4	1392	3125	4502	0.31	1363	3100	4464	0.30	1378
v_3f_5	1298	2829	4112	0.34	1267	3120	4066	0.31	1282
v_3f_6	1161	2619	3765	0.31	1129	2819	3710	0.30	1145
v_4f_1	1100	2243	3328	0.33	1095	2601	3354	0.33	1098
v_4f_2	1199	2500	3684	0.32	1088	2279	3381	0.32	1144
v_4f_3	1309	2769	4063	0.32	1218	2314	3825	0.32	1263
v_4f_4	1268	2564	3817	0.32	1283	2627	3908	0.33	1275
v_4f_5	1301	2774	4060	0.33	1249	2645	3944	0.32	1275
v_4f_6	1041	2131	3157	0.32	1122	2715	3441	0.32	1081
v_5f_1	1336	2564	3885	0.33	1304	2340	3837	0.34	1320
v_5f_2	1245	2585	3816	0.34	1207	2553	3745	0.32	1226
v_5f_3	1362	2898	4245	0.32	1395	2558	4399	0.32	1378
v_5f_4	1557	3112	4654	0.34	1483	3024	4487	0.33	1520
v_5f_5	1442	2966	4393	0.33	1387	2911	4278	0.32	1414
v_5f_6	1258	2919	4163	0.30	1111	2627	3718	0.30	1184
SEm(±)	42.0	89.3	97.5	0.01	43.6	95.5	104.9	0.01	29.1
CD (0.05)	118.43	254.64	278.31	NS	125.91	274.54	299.63	NS	81.17

NS - Not significant

during both the seasons (5028 kg ha^{-1} and 5020 kg ha^{-1} in the summer and 4900 kg ha^{-1} and 4865 kg ha^{-1} in the *Rabi* respectively).

There was significant difference TDMP with foliar spray in both the seasons. The highest TDMP was recorded due to foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) in summer and *Rabi* season (4835 kg ha^{-1} and 4786 kg ha^{-1} respectively).

Regarding the interaction effects, the treatment combinations v_1f_4 and v_2f_4 were on par (5635 and 5569 kg ha^{-1}) during summer season and in *Rabi*, the highest TDMP was recorded in the treatment combination v_1f_4 (5728 kg ha^{-1}).

4.2.5.10 Harvest Index

The data on effect of varieties, foliar spray and their interaction on harvest index are given in Tables 27a and 27b. There was no significant difference in harvest index due to varieties and foliar spray in both the seasons. The interaction effect was not significant with respect to harvest index during both the seasons.

4.2.5.11 Season wise Comparison of growth and yield of Sumanjana and DBGV 5 under the Best Foliar spray (f_4) identified

Table 27c represents season wise comparison of growth and yield of Sumanjana and DBGV 5 under the best foliar spray (f_4). The growth characters *viz*., plant height and leaf area index were higher in summer compared to *Rabi*. Number of nodules per plant, total chlorophyll content and stomatal conductance were higher during Rabi season compared to summer season. Sumanjana (v_1) and DBGV 5 (v_2) marked early flowering during summer season. Number of pods per plant, seed yield and haulm yield recorded were higher in summer season in v_1f_4 and v_2f_4 compared to *Rabi* season.

Table 27c. Season wise comparison of growth and yield of Sumanjana (v_1) and DBGV 5 (v_2) under the best foliar spray (f_4)

Particulars	Summer		*Rabi*	
	v_1f_4	v_2f_4	v_1f_4	v_2f_4
Plant height (cm)	97.70	93.84	91.45	73.99
Leaf area index at flowering	6.71	4.12	6.10	6.03
Number of nodules per plant at flowering	25.80	24.53	33.0	30.54
Total chlorophyll (mg g^{-1} fresh tissue) at flowering	2.15	1.99	2.58	2.39
Stomatal conductance (m moles m^{-2} s^{-1}) at flowering	33.0	30.61	35.20	31.95
Days to 50% flowering	34.20	36.0	37.86	39.85
Number of pods per plant	30.24	28.30	29.40	27.26
Seed yield (kg ha^{-1})	1750	1713	1700	1538
Haulm yield (kg ha^{-1})	3900	3870	4048	3827

4.2.6 Quality Parameters

The quality characters *viz.*, grain dry matter, grain protein and nitrate content of grain were computed at harvest and the results are presented in Tables 28a and 28b.

4.2.6.1 Grain Dry Matter

There was no significant variation in grain dry matter due to varieties and foliar spray in both the seasons. The interaction effect also did not show any variation in grain dry matter (Table 28b).

4.2.6.2 Grain Protein

The data on variation in grain protein content due to varieties, foliar spray and their interaction are given in Tables 28a and 28b. There was no significant variation in grain protein content due to varieties during both the seasons.

Foliar spray had significant influence on grain protein content in summer season and foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in higher grain protein content (23.12%) and was on par with all other treatments except f_2 and f_6. There was no significant variation in grain protein content due to interaction in both the seasons.

4.2.6.3 Nitrate Content

The perusal of data in Tables 28a and 28b revealed that, there was no significant variation in nitrate content due to main plot, subplot and interaction effect in both the seasons under study. In general, nitrate content was found to be higher in summer compared to *Rabi.*

Table 28a. Effect of varieties and foliar application on grain dry matter, protein and nitrate content during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
	Grain dry matter (%)	Grain protein (%)	NO_3 content (µg NO_3^- g^{-1})	Grain dry matter (%)	Grain protein (%)	NO_3 content (µg NO_3^- g^{-1})
Main plot - Varieties (V)						
v_1 – Sumanjana	91.24	22.20	0.1620	90.74	23.56	0.156
v_2 - DBGV 5	91.45	22.55	0.1615	90.95	23.14	0.153
v_3 - VBN 5	89.40	21.37	0.1608	88.9	22.86	0.151
v_4 - VBN 6	88.88	22.23	0.1610	88.38	22.96	0.152
v_5 - CO 6	90.16	21.91	0.1598	89.67	22.99	0.152
SEm(±)	0.92	0.21	0.0020	0.68	0.25	0.002
CD (0.05)	NS	NS	NS	NS	NS	NS
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	90.01	21.85	0.1607	89.51	22.88	0.152
f_2 - Foliar spray of SOP @ 0.5%	89.52	21.22	0.1625	89.02	23.21	0.154
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	90.67	22.33	0.1608	90.17	23.04	0.152
f_4 - f_3 + f_1	91.15	23.12	0.1603	90.65	23.68	0.157
f_5 - f_3 + f_2	90.69	22.78	0.1610	90.19	22.87	0.151
f_6 - Control (KAU POP)	89.32	21.00	0.1610	88.82	22.94	0.152
SEm(±)	0.98	0.30	0.0018	1.19	0.66	0.002
CD (0.05)	NS	0.843	NS	NS	NS	NS

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 28b. Interaction effect of varieties and foliar application on grain dry matter, protein and nitrate content of blackgram during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
	Grain dry matter (%)	Grain protein (%)	NO_3 content (µg NO_3^- g^{-1})	Grain dry matter (%)	Grain protein (%)	NO_3 content (µg NO_3^- g^{-1})
v_1f_1	91.50	22.55	0.163	90.99	22.48	0.149
v_1f_2	90.53	20.06	0.162	90.03	23.83	0.157
v_1f_3	91.41	22.74	0.161	90.91	24.02	0.152
v_1f_4	92.21	24.80	0.161	91.70	23.93	0.152
v_1f_5	91.83	23.08	0.163	91.32	23.80	0.149
v_1f_6	89.96	20.00	0.162	89.46	23.31	0.158
v_2f_1	91.51	22.89	0.161	91.01	23.67	0.157
v_2f_2	91.27	23.04	0.159	90.77	23.77	0.149
v_2f_3	91.64	23.00	0.161	91.13	22.48	0.147
v_2f_4	92.01	23.00	0.160	91.50	23.96	0.158
v_2f_5	91.71	23.08	0.164	91.20	22.48	0.159
v_2f_6	90.58	20.29	0.165	90.08	22.48	0.149
v_3f_1	88.89	20.40	0.161	88.40	22.86	0.149
v_3f_2	88.53	20.50	0.161	88.04	22.48	0.155
v_3f_3	90.29	21.00	0.160	89.79	22.48	0.151
v_3f_4	90.46	22.40	0.163	89.96	23.83	0.158
v_3f_5	89.73	22.50	0.160	89.23	22.48	0.158
v_3f_6	88.48	21.40	0.160	87.99	23.06	0.158
v_4f_1	88.12	22.30	0.159	87.63	22.93	0.155
v_4f_2	88.04	21.50	0.170	87.56	22.12	0.154
v_4f_3	89.32	22.50	0.161	88.83	23.44	0.158
v_4f_4	89.86	22.40	0.158	89.36	23.35	0.149
v_4f_5	89.58	22.44	0.159	89.08	23.09	0.149
v_4f_6	88.34	22.21	0.157	87.85	22.83	0.153
v_5f_1	90.02	21.14	0.159	89.52	22.48	0.149
v_5f_2	89.22	21.00	0.160	88.73	23.83	0.155
v_5f_3	90.67	22.40	0.160	90.17	22.80	0.149
v_5f_4	91.23	23.00	0.160	90.73	23.32	0.153
v_5f_5	90.62	22.80	0.159	90.12	22.48	0.151
v_5f_6	89.22	21.10	0.161	88.73	23.02	0.152
SEm(±)	2.20	0.64	0.004	2.52	0.66	0.004
CD (0.05)	NS	NS	NS	NS	NS	NS

NS - Not significant

4.2.7 Plant Analysis

4.2.7.1 NPK Content

The data on NPK content of plant as affected by varieties and foliar spray are given in Tables 29a and 29b.

There was no significant variation in N and K contents due to varieties and foliar spray in both the seasons. Regarding P content, significant variation was observed among varieties and Sumanjana recorded higher P content in both the seasons and was on par with CO 6 (0.52% and 0.48% in summer and 0.49% and 0.48 % in *Rabi* respectively).

There was no significant difference in P content due to foliar spray in summer season. In *Rabi*, the highest value of P content (0.48) was registered with the foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4).

Among the interactions, v x f indicated significant variation with respect to P content only during *Rabi*. In *Rabi*, higher P content was recorded in v_1f_4 which was on par with v_1f_1 (0.53%).

4.2.7.2 Uptake of NPK

The data on the effect of varieties, foliar spray and their interaction on NPK uptake of blackgram during the both the seasons are given in Tables 30a and 30b. There was significant variation in NPK uptake due to treatments.

Among the varieties, DBGV 5 recorded higher N uptake (132.70 kg ha^{-1}) and was on par with Sumanjana (129.27 kg ha^{-1}) during the summer season and the highest value of N uptake was recorded by Sumanjana (128.28 kg ha^{-1}) in the *Rabi* season. The lowest N uptake was by VBN 6 during both the seasons. Foliar spray of 19:19:19 (1%)

Table 29a. Effect of varieties and foliar application on N, P and K content during summer 2020 and *Rabi* 2020-21, per cent

Treatments	Summer 2020			*Rabi* 2020-21		
	N	P	K	N	P	K
Main plot - Varieties (V)						
v_1 – Sumanjana	3.58	0.52	3.74	3.58	0.49	3.77
v_2 - DBGV 5	3.50	0.42	3.66	3.49	0.43	3.62
v_3 - VBN 5	3.60	0.45	3.74	3.65	0.46	3.78
v_4 - VBN 6	3.66	0.41	3.72	3.59	0.41	3.75
v_5 - CO 6	3.68	0.48	3.84	3.59	0.48	3.79
SEm(±)	0.03	0.02	0.03	0.04	0.01	0.06
CD (0.05)	NS	0.030	NS	NS	0.017	NS
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	3.59	0.44	3.75	3.58	0.45	3.80
f_2 - Foliar spray of SOP @ 0.5%	3.60	0.45	3.76	3.60	0.45	3.73
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	3.52	0.45	3.68	3.55	0.43	3.64
f_4 - f_3 + f_1	3.60	0.47	3.76	3.60	0.48	3.70
f_5 - f_3 + f_2	3.64	0.47	3.78	3.57	0.46	3.81
f_6 - Control (KAU POP)	3.66	0.46	3.72	3.58	0.43	3.78
SEm(±)	0.06	0.01	0.05	0.05	0.01	0.06
CD (0.05)	NS	NS	NS	NS	0.019	NS

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 29b. Interaction effect of varieties and foliar application on N, P and K content during summer 2020 and *Rabi* 2020-21, per cent

Treatments	Summer 2020			*Rabi* 2020-21		
	N content	P content	K content	N content	P content	K content
v_1f_1	3.64	0.52	3.82	3.65	0.53	3.79
v_1f_2	3.42	0.54	3.59	3.41	0.52	3.59
v_1f_3	3.45	0.50	3.62	3.46	0.41	3.53
v_1f_4	3.75	0.51	3.84	3.74	0.57	3.96
v_1f_5	3.55	0.52	3.73	3.54	0.49	3.85
v_1f_6	3.67	0.55	3.86	3.66	0.43	3.88
v_2f_1	3.39	0.38	3.56	3.40	0.43	3.65
v_2f_2	3.63	0.42	3.82	3.62	0.47	3.69
v_2f_3	3.38	0.43	3.55	3.37	0.42	3.52
v_2f_4	3.47	0.42	3.64	3.47	0.41	3.44
v_2f_5	3.39	0.41	3.56	3.37	0.42	3.53
v_2f_6	3.71	0.44	3.85	3.70	0.47	3.91
v_3f_1	3.77	0.45	3.84	3.75	0.46	4.02
v_3f_2	3.58	0.44	3.76	3.60	0.43	3.76
v_3f_3	3.48	0.45	3.65	3.68	0.46	3.65
v_3f_4	3.63	0.49	3.81	3.69	0.51	3.65
v_3f_5	3.75	0.48	3.85	3.51	0.49	3.92
v_3f_6	3.39	0.41	3.56	3.68	0.41	3.68
v_4f_1	3.48	0.40	3.65	3.61	0.39	3.58
v_4f_2	3.71	0.39	3.77	3.67	0.38	3.77
v_4f_3	3.75	0.40	3.88	3.48	0.40	3.93
v_4f_4	3.47	0.44	3.65	3.63	0.44	3.55
v_4f_5	3.69	0.43	3.87	3.75	0.45	3.98
v_4f_6	3.84	0.42	3.5	3.39	0.39	3.7
v_5f_1	3.68	0.47	3.87	3.48	0.46	3.95
v_5f_2	3.69	0.45	3.87	3.71	0.47	3.82
v_5f_3	3.51	0.49	3.69	3.75	0.49	3.58
v_5f_4	3.68	0.50	3.86	3.47	0.50	3.88
v_5f_5	3.82	0.51	3.87	3.69	0.49	3.76
v_5f_6	3.67	0.47	3.85	3.45	0.47	3.79
SEm(±)	0.13	0.02	0.10	0.11	0.01	0.14
CD (0.05)	NS	NS	NS	NS	0.042	NS

NS - Not significant

at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded higher N uptake (124.13 kg ha^{-1}) and was on par with f_3 (119.85 kg ha^{-1}) and f_5 (122.96 kg ha^{-1}) in summer season and the highest N uptake (123.43 kg ha^{-1}) was recorded in f_4 during *Rabi*. The interaction of varieties and foliar spray recorded significant variation in N uptake during *Rabi* season. Sumanjana with a combination spray of NPK and plant growth regulators (v_1f_4) proved superior with respect to N uptake (148.83 kg ha^{-1}), followed by v_1f_1 (130.81 kg ha^{-1}). The lowest N uptake was recorded in v_4f_6 (86.15 kg ha^{-1}) and was on par with v_4f_1 and v_4f_2.

There was significant difference in P uptake due to varieties and foliar spray. The highest P uptake was recorded in Sumanjana in both the seasons (18.89 kg ha^{-1} and 17.69 kg ha^{-1} respectively) and the lowest P uptake recorded by VBN 8 (11.29 kg ha^{-1} and 11.01 kg ha^{-1}) during both the seasons. During summer season, P uptake was significantly higher with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) and was on par with f_3 and f_5 (16.31 kg ha^{-1}, 15.57 kg ha^{-1} and 15.91 kg ha^{-1} respectively). In the *Rabi* season, significantly higher P uptake was recorded in f_4 (16.75 kg ha^{-1}). There was no significant difference in P uptake due to interaction effect in summer season. The treatment combination v_1f_4 recorded the highest P uptake of 22.68 kg ha^{-1} during *Rabi*.

The results revealed significant influence of varieties and foliar spray on K uptake in blackgram. The variety DBGV 5 recorded higher K uptake (139.38 kg ha^{-1}) in summer and was on par with Sumanjana (135.05 kg ha^{-1}) and in *Rabi*, the highest K uptake was recorded by Sumanjana (135.10 kg ha^{-1}). Foliar spray had significant effect in K uptake with f_4 resulting in higher K uptake which was comparable with f_5 and f_3 during summer (129.75 kg ha^{-1}, 127.47 kg ha^{-1} and 125.64 kg ha^{-1} respectively). In *Rabi*, the highest K uptake was recorded in f_4 (126.97 kg ha^{-1}). In the case of interaction, there was no significant difference in K uptake in summer season and the highest K

Table 30a. Effect of varieties and foliar application on N, P and K uptake during summer 2020 and *Rabi* 2020-21, kg ha^{-1}

Treatments	Summer 2020			*Rabi* 2020-21		
	N uptake	P uptake	K uptake	N uptake	P uptake	K uptake
Main plot - Varieties (V)						
v_1 - Sumanjana	129.27	18.89	135.05	128.28	17.69	135.10
v_2 - DBGV 5	132.70	15.84	139.38	122.80	15.35	127.46
v_3 - VBN 5	108.45	13.71	112.87	107.46	13.60	111.15
v_4 - VBN 6	99.50	11.29	102.68	96.35	11.01	100.81
v_5 - CO 6	115.02	15.12	119.83	107.94	14.45	113.68
SEm(±)	1.37	1.33	1.59	1.20	0.23	1.15
CD (0.05)	4.212	0.433	4.742	3.698	0.718	3.550
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	113.53	14.12	118.58	109.44	14.04	116.32
f_2 - Foliar spray of SOP @ 0.5%	111.16	14.00	116.43	107.92	13.8	111.66
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	119.85	15.57	125.64	115.69	14.23	118.48
f_4 - f_3 + f_1	124.13	16.31	129.75	123.43	16.75	126.97
f_5 - f_3 + f_2	122.96	15.91	127.47	115.00	15.08	122.57
f_6 - Control (KAU POP)	110.31	13.91	113.91	103.92	12.62	109.83
SEm(±)	2.68	0.48	2.42	1.51	0.16	1.38
CD (0.05)	7.564	1.346	6.807	4.260	0.436	3.881

f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 30b. Interaction effect of varieties and foliar application on N, P and K uptake of blackgram during summer 2020 and *Rabi* 2020-21, kg ha^{-1}

Treatments	Summer 2020			*Rabi* 2020-21		
	N uptake	P uptake	K uptake	N uptake	P uptake	K uptake
v_1f_1	139.31	19.87	145.77	130.81	18.98	135.74
v_1f_2	121.00	19.06	126.94	118.63	18.10	124.98
v_1f_3	130.59	18.92	137.15	124.44	14.75	126.96
v_1f_4	131.23	18.09	134.45	148.83	22.68	157.59
v_1f_5	131.94	19.37	138.46	122.80	17.01	133.65
v_1f_6	121.53	18.05	127.53	124.18	14.59	131.65
v_2f_1	126.83	14.22	134.09	122.81	15.53	131.84
v_2f_2	136.80	15.96	144.65	127.50	16.54	129.88
v_2f_3	130.04	16.36	136.77	119.35	14.86	124.57
v_2f_4	141.44	17.14	148.56	128.12	15.14	127.01
v_2f_5	132.29	15.96	138.33	122.71	15.29	128.54
v_2f_6	128.83	15.38	133.86	116.30	14.77	122.90
v_3f_1	106.48	12.74	108.29	105.09	12.90	112.73
v_3f_2	100.25	12.38	105.51	99.71	11.92	114.21
v_3f_3	114.06	14.76	119.81	115.64	14.44	114.62
v_3f_4	120.70	16.30	126.75	120.28	16.62	118.97
v_3f_5	114.18	14.65	117.71	104.45	14.59	116.74
v_3f_6	95.00	11.40	99.14	99.61	11.10	99.61
v_4f_1	87.32	10.01	91.65	89.25	9.66	88.63
v_4f_2	92.84	9.79	94.95	91.44	9.46	93.87
v_4f_3	111.10	11.97	115.41	97.81	11.25	110.54
v_4f_4	100.53	12.70	105.86	104.82	12.71	102.51
v_4f_5	111.26	12.98	116.87	108.64	13.04	115.30
v_4f_6	93.97	10.30	91.36	86.15	9.91	94.03
v_5f_1	107.70	13.74	113.09	99.24	13.12	112.64
v_5f_2	104.92	12.82	110.10	102.33	12.96	105.37
v_5f_3	113.45	15.81	119.05	121.20	15.84	115.71
v_5f_4	126.75	17.32	133.10	115.10	16.60	128.79
v_5f_5	125.11	16.60	125.98	116.40	15.46	118.60
v_5f_6	112.20	14.44	117.67	93.37	12.72	100.95
SEm(±)	5.65	1.07	5.17	3.31	0.39	3.04
CD (0.05)	NS	NS	NS	9.445	1.143	8.677

NS - Not significant

uptake was recorded in the treatment combination wherein Sumanjana was supplied with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) in the *Rabi* (157.59 kg ha^{-1}).

4.2.8 Soil Analysis

4.2.8.1 Soil pH

The data in table 31a and 31b shows the variation in soil pH due to varieties, foliar spray and their interaction during summer and *Rabi* respectively.

Perusal of the data revealed that the soil pH did not vary significantly with varieties and foliar spray in both the seasons. The interaction also did not record any significant variation in both the seasons under study. However, soil pH showed significant variation with respect to foliar nutrition during *Rabi.*

4.2.8.2 Electrical Conductivity

The data in Table 31a and 31b shows the variation in electrical conductivity (EC) with respect to varieties and foliar spray in both the seasons. The results showed that the variation on EC was not significant due to varieties, and foliar spray during both the seasons. In the case of interaction also, the treatments failed to produce any significant difference in electrical conductivity in both the seasons.

4.2.8.3 Organic Carbon

The data in Tables 31a and 31b represents the effect of varieties and foliar spray on soil organic carbon after the experiment during both the seasons. There was no significant variation in organic carbon due to varieties and foliar spray and their interaction in summer. During the *Rabi*, organic carbon content was higher (0.96%) in the soil, where the variety Sumanjana was raised and was on par with DBGV 5 (0.95%).

Table 31a. Effect of varieties and foliar application on soil pH, EC and organic carbon content during summer 2020 and *Rabi* 2020-21

Treatments	Summer 2020			*Rabi* 2020-21		
	Soil pH	EC (ds m^{-1})	Organic carbon (%)	Soil pH	EC (ds m^{-1})	Organic carbon (%)
Main plot - Varieties (V)						
v_1 – Sumanjana	6.28	0.168	0.98	5.98	0.155	0.96
v_2 - DBGV 5	6.23	0.170	0.95	5.78	0.150	0.95
v_3 - VBN 5	6.21	0.167	0.93	5.67	0.150	0.78
v_4 - VBN 6	6.23	0.168	0.96	5.73	0.150	0.79
v_5 - CO 6	6.22	0.175	0.96	5.74	0.152	0.94
SEm(±)	0.06	0.002	0.02	0.09	0.001	0.03
CD (0.05)	NS	NS	NS	NS	NS	0.011
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	6.22	0.171	0.96	5.71	0.149	0.89
f_2 - Foliar spray of SOP @ 0.5%	6.22	0.171	0.93	5.77	0.153	0.89
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	6.24	0.169	0.97	5.73	0.151	0.84
f_4 - f_3 + f_1	6.25	0.165	0.95	6.04	0.157	1.04
f_5 - f_3 + f_2	6.22	0.169	0.96	5.69	0.150	0.93
f_6 - Control (KAU POP)	6.25	0.175	0.97	5.74	0.150	0.71
SEm(±)	0.017	0.003	0.01	0.08	0.002	0.01
CD (0.05)	NS	NS	NS	0.230	NS	0.034

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 31b. Interaction effect of varieties and foliar application on soil pH, EC and organic carbon content during summer and *Rabi*

Treatments	Summer 2020			*Rabi* 2020-21		
	Soil pH	EC (ds m^{-1})	Organic carbon	Soil pH	EC (ds m^{-1})	Organic carbon (%)
v_1f_1	6.23	0.168	0.99	5.61	0.145	0.93
v_1f_2	6.24	0.168	0.95	5.95	0.155	1.01
v_1f_3	6.26	0.168	0.99	5.99	0.160	0.99
v_1f_4	6.29	0.158	0.94	6.61	0.160	1.09
v_1f_5	6.28	0.165	1.02	5.93	0.155	0.93
v_1f_6	6.40	0.180	0.98	5.82	0.155	0.82
v_2f_1	6.22	0.178	0.96	5.91	0.155	0.93
v_2f_2	6.24	0.168	0.91	5.93	0.155	0.96
v_2f_3	6.24	0.175	0.98	5.53	0.145	0.85
v_2f_4	6.25	0.158	0.97	5.98	0.158	1.09
v_2f_5	6.22	0.168	0.99	5.61	0.145	1.04
v_2f_6	6.20	0.178	0.92	5.70	0.145	0.82
v_3f_1	6.20	0.168	0.90	5.71	0.150	0.84
v_3f_2	6.19	0.175	0.91	5.50	0.148	0.82
v_3f_3	6.22	0.158	0.93	5.61	0.148	0.55
v_3f_4	6.23	0.168	0.95	5.95	0.158	1.01
v_3f_5	6.19	0.158	0.91	5.52	0.150	0.93
v_3f_6	6.20	0.175	1.01	5.76	0.150	0.55
v_4f_1	6.22	0.173	0.98	5.72	0.150	0.88
v_4f_2	6.21	0.168	0.95	5.52	0.148	0.74
v_4f_3	6.24	0.175	1.01	5.85	0.153	0.82
v_4f_4	6.25	0.158	0.89	5.83	0.153	0.93
v_4f_5	6.21	0.168	0.97	5.76	0.150	0.82
v_4f_6	6.22	0.170	0.98	5.70	0.148	0.55
v_5f_1	6.21	0.168	0.97	5.61	0.145	0.87
v_5f_2	6.20	0.175	0.92	5.95	0.158	0.95
v_5f_3	6.23	0.168	0.96	5.69	0.148	0.98
v_5f_4	6.24	0.183	0.97	5.82	0.158	1.09
v_5f_5	6.20	0.188	0.94	5.61	0.150	0.93
v_5f_6	6.21	0.173	0.97	5.75	0.153	0.82
SEm(±)	0.16	0.006	0.03	0.19	0.004	0.27
CD (0.05)	NS	NS	NS	NS	NS	0.077

NS - Not significant

There was significant variation in organic carbon due to foliar spray in *Rabi* and the treatment 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded the highest organic carbon (1.04%). The lowest organic carbon content was recorded in f_6 (0.71%).

There was no significant difference in organic carbon due to interaction in summer season. In the *Rabi* season, the treatment combinations v_1f_4, v_2f_4, v_5f_4, v_2f_5, and v_1f_2 recorded higher organic carbon content and were on par with each other (1.09%, 1.09%, 1.09%, 1.04% and 1.01% respectively).

4.2.8.4 Available NPK

The available NPK status of soil after the experiment is presented in Table 32a and 32b.

There was significant variation in soil available N in both the seasons due to varieties, foliar spray and their interaction. During summer season, the highest soil N status was recorded in soils with the variety Sumanjana (188.16 kg ha^{-1}), while in *Rabi*, the plots with Sumanjana (v_1) and DBGV 5 (v_2) were on par (209.42 kg ha^{-1} and 206.32 kg ha^{-1}). In the case of subplot factor, foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded significantly higher N status in both the seasons (208.23 kg ha^{-1} and 223.25 kg ha^{-1} respectively). The interaction effect was also significant in both the seasons. In summer, maximum mean value of 225.79 kg ha^{-1} was recorded in the treatment combination Sumanjana with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4). During the *Rabi*, the treatment combination v_2f_4 (237.98 kg ha^{-1}) recorded higher N status (237.43 kg ha^{-1} and 225.97 kg ha^{-1}) and was on par with v_1f_4 and v_2f_5.

There was no significant difference in soil P status due to varieties, foliar spray and their interaction during summer season. During *Rabi*, there was significant

Table 32a. Effect of varieties and foliar application on available N, P and K status of the soil during summer 2020 and *Rabi* 2020-21, kg ha^{-1}

Treatments	Summer 2020			*Rabi* 2020-21		
	Available N	Available P	Available K	Available N	Available P	Available K
Main plot - Varieties (V)						
v_1 - Sumanjana	188.16	37.06	376.90	209.42	40.08	366.97
v_2 - DBGV 5	184.50	36.26	370.41	206.32	38.68	360.38
v_3 - VBN 5	175.62	35.67	362.34	170.57	37.98	356.13
v_4 - VBN 6	175.62	36.55	371.27	171.94	38.38	357.63
v_5 - CO 6	171.43	36.40	367.23	201.78	38.45	358.05
SEm(±)	0.24	0.49	4.36	1.99	0.59	5.03
CD (0.05)	0.7204	NS	NS	6.139	NS	NS
Sub plot - Foliar spray (F)						
f_1 - Foliar spray of 19:19:19 @ 1%	191.30	36.41	369.81	194.31	38.25	356.43
f_2 - Foliar spray of SOP @ 0.5%	163.07	35.42	360.07	195.19	38.64	361.43
f_3 - NAA 40 mg L^{-1} & SA 100 mg L^{-1}	165.58	36.98	375.59	182.20	38.42	358.93
f_4 - f_3 + f_1	208.23	35.91	364.70	223.25	40.41	368.74
f_5 - f_3 + f_2	175.62	36.66	372.32	202.28	38.08	356.13
f_6 - Control (KAU POP)	170.60	36.95	375.28	154.80	38.47	357.33
SEm(±)	0.26	0.46	4.45	2.67	0.52	5.16
CD (0.05)	0.721	NS	NS	7.515	1.475	NS

NS - Not significant f_1, f_2 - 45 and 60 DAS ; f_3- pre flowering (30-35 DAS) and 15 days later

Table 32b. Interaction effect of varieties and foliar application on available N, P and K status of the soil during summer 2020 and *Rabi* 2020-21, kg ha^{-1}

Treatments	Summer 2020			*Rabi* 2020-21		
	Available N	Available P	Available K	Available N	Available P	Available K
v_1f_1	200.70	37.43	380.18	202.50	37.61	350.13
v_1f_2	175.62	35.38	362.31	219.97	39.85	371.14
v_1f_3	163.07	37.80	383.92	215.60	40.13	374.14
v_1f_4	225.79	35.60	361.58	237.43	44.20	372.64
v_1f_5	188.16	38.75	393.57	202.50	39.71	370.64
v_1f_6	175.62	37.40	379.86	178.49	39.01	363.14
v_2f_1	191.30	36.40	369.70	201.96	39.57	368.64
v_2f_2	163.07	34.50	363.37	208.51	39.71	370.14
v_2f_3	175.62	37.20	377.83	184.49	37.04	350.13
v_2f_4	213.25	36.90	374.78	237.98	39.99	373.14
v_2f_5	188.16	37.50	380.87	225.97	37.61	350.13
v_2f_6	175.62	35.04	355.89	179.03	38.17	350.13
v_3f_1	200.70	34.24	347.76	183.94	38.17	356.13
v_3f_2	163.07	35.63	362.10	178.49	36.76	350.13
v_3f_3	175.62	35.20	357.51	118.99	37.61	350.13
v_3f_4	188.16	36.04	366.05	220.51	39.85	371.14
v_3f_5	150.53	34.52	350.61	202.50	36.90	350.13
v_3f_6	175.62	38.40	390.02	118.99	38.59	359.14
v_4f_1	188.16	37.18	377.63	192.68	38.31	357.14
v_4f_2	163.07	35.92	364.80	161.02	37.05	344.63
v_4f_3	150.53	38.20	387.98	177.94	39.15	365.14
v_4f_4	213.25	34.00	345.33	202.50	39.01	363.64
v_4f_5	175.62	36.80	373.76	178.49	38.59	359.64
v_4f_6	163.07	37.23	378.13	118.99	38.17	355.63
v_5f_1	175.62	36.80	373.76	190.49	37.61	350.13
v_5f_2	150.53	35.69	347.76	207.96	39.85	371.14
v_5f_3	163.07	36.50	370.72	213.96	38.17	355.13
v_5f_4	200.70	37.00	375.80	217.82	39.01	363.14
v_5f_5	175.62	35.72	362.80	201.96	37.61	350.13
v_5f_6	163.07	36.68	372.53	178.49	38.45	358.63
SEm(±)	0.57	1.06	10.08	5.80	1.22	11.67
CD (0.05)	1.638	NS	NS	16.514	NS	NS

NS - Not significant

variation only due to foliar spray and the highest P status (40.41 kg ha^{-1}) was recorded with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4). There was no significant variation in soil available P due to varieties, foliar spray and their interaction in *Rabi*.

Perusal of data in Table 32a revealed that, there was no significant difference in soil available K status due to varieties, foliar spray and their interaction in both the seasons.

4.2.9 Pest and Disease Incidence

In the present study, during both the seasons, pest and disease incidence were noticed but they were below the prescribed economic threshold level. At 20-30 DAS, tobacco caterpillar (*Spodoptera litura*) incidence was noticed and it was controlled using quinolphos 25 EC (KRUSH) @ 2 mL L^{-1}. At reproductive stage (60-75 DAS) spotted pod borer (*Maruca vitrata*) observed was controlled using chlorantraniliprole 18.5 SC (CORAGEN) @ 3 mL 10 L^{-1} twice weekly interval. Consequent to rain, the incidence of collar rot disease (*Rhizctonia solani)* was noticed and it was managed with carbendazim (BAVISTIN 50 WP) @ 1g L^{-1} at pod maturity stage.

4.2.10 Economic Analysis

The economics of blackgram intercropped in coconut garden in summer and *Rabi* seasons are presented in Tables 33. There was significant difference in gross income, net income and benefit cost ratio in both the seasons.

In summer, higher gross income, net income and BCR were recorded in the treatment combination v_1f_4 (₹ 139,976 ha^{-1}, ₹ 72384 ha^{-1} and 2.07 respectively) followed by v_2f_4 (₹ 137,077 ha^{-1}, ₹ 68544 ha^{-1} and 2.0 respectively). In *Rabi* also, gross income, net income and BCR were recorded were the highest for the treatment combination v_1f_4 (₹136,031 ha^{-1}, ₹ 68439 ha^{-1} and 2.01) followed by v_2f_4. The highest

Table 33. Economics of blackgram cultivation as influenced by varieties and foliar application during summer 2020 and *Rabi* 2020-21

Treatments	Cost of cultivation (₹ ha^{-1})	Summer 2020			*Rabi* 2020-21			Mean net income (₹ ha^{-1})	Mean BCR
		Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	BCR	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	BCR		
v_1f_1	61974	117920	55946	1.90	112147	50173	1.81	53060	1.86
v_1f_2	61499	111938	50440	1.82	110318	48820	1.79	49630	1.81
v_1f_3	62742	121982	59240	1.94	113142	50400	1.80	54820	1.87
v_1f_4	67592	139976	72384	2.07	136031	68439	2.01	70411	2.04
v_1f_5	67117	129440	62323	1.93	120553	53435	1.80	57879	1.87
v_1f_6	56284	113192	56908	1.92	97441	41157	1.73	49033	1.83
v_2f_1	61974	120247	58273	1.94	114183	52209	1.84	55241	1.89
v_2f_2	61499	115798	54300	1.88	114066	52567	1.85	53433	1.87
v_2f_3	62742	121982	59240	1.94	119074	54332	1.80	57786	1.87
v_2f_4	68532	137077	68544	2.00	123040	56508	1.90	61526	1.95
v_2f_5	68057	123083	55026	1.81	122195	54138	1.80	54582	1.81
v_2f_6	56284	102206	45923	1.82	101313	45029	1.80	45476	1.81
v_3f_1	61974	94506	32533	1.52	93666	31693	1.51	32113	1.52
v_3f_2	61499	91946	30448	1.50	90753	29254	1.48	29851	1.49
v_3f_3	62742	109866	47124	1.75	105183	42441	1.68	44782	1.72
v_3f_4	68532	111360	42828	1.62	109070	40537	1.59	41682	1.61
v_3f_5	68057	103803	35746	1.53	101368	33311	1.49	34528	1.51
v_3f_6	56284	92843	36559	1.65	90336	34052	1.61	35306	1.63
v_4f_1	61974	88036	26062	1.42	87630	25657	1.41	25859	1.42
v_4f_2	61499	95957	34458	1.56	87006	25507	1.41	29982	1.49
v_4f_3	62742	104716	41974	1.67	97414	34671	1.55	38322	1.61
v_4f_4	68532	101444	32912	1.48	102617	34084	1.50	33498	1.49
v_4f_5	68057	104106	36049	1.53	99911	31854	1.47	33951	1.50
v_4f_6	56284	83251	26967	1.48	89722	33439	1.59	30203	1.54
v_5f_1	61974	106880	44906	1.72	104282	42309	1.68	43607	1.70
v_5f_2	61499	99626	38128	1.62	96581	35082	1.57	36605	1.60
v_5f_3	62742	108965	46222	1.74	111567	48825	1.78	47524	1.76
v_5f_4	68532	124575	56043	1.82	118645	50112	1.73	53078	1.78
v_5f_5	68057	115321	47263	1.69	110943	42886	1.63	45075	1.66
v_5f_6	56284	100662	44378	1.79	88850	32567	1.58	38472	1.69

* Data not statistically analysed

mean net income and BCR were also recorded in the treatment combination v_1f_4 (₹ 70411 ha^{-1} and 2.04 respectively) followed by v_2f_4 (₹ 61526 ha^{-1} and 1.95 respectively).

The results of experiment II revealed that among the varieties, Sumanjana performed better in terms of growth characters, physiological parameters and yield attributes. Among the foliar sprays, f_4 resulted in higher growth and yield attributes compared to control. Among the treatment combinations, v_1f_4 and v_2f_4 recorded higher yield, net income and B: C ratio during both the seasons.

DISCUSSION

5. DISCUSSION

The investigation entitled 'Productivity enhancement of blackgram (*Vigna mungo* (L.) Hepper) intercropped in coconut gardens' was undertaken to identify shade tolerant blackgram varieties suitable for coconut gardens for cultivation in Kerala and to study the effect of foliar nutrition and plant growth regulators on growth and yield of the shade tolerant blackgram varieties intercropped in coconut garden. The investigation was conducted as two separate experiments. The results of the experiment presented in the previous chapter are discussed with available documented literature to justify and substantiate the findings of present study.

5.1 EXPERIMENT I - SCREENING OF BLACKGRAM VARIETIES FOR SHADE TOLERANCE (MICRO PLOT STUDY)

5.1.1 Growth Characters

The growth characters *viz.*, plant height, number of leaves per plant, number of branches per plant at monthly interval and leaf are index (LAI) at 50 per cent flowering of varieties and cultures under partial shade showed varied response during the entire crop season (Table 1 to Table 4). Among the varieties, DBGV 5, CO 6 and Sumanjana were found to grow taller from one month after sowing (MAS) till harvest under low light while Culture 4.5.18, Culture 4.5.8 and VBN 5 maintained a shorter stature. Increased plant height is an adaptation to grow better in low light intensity. The varieties that grew taller (DBGV 5, CO 6 and Sumanjana) were found adapted to partially shaded conditions by stem elongation for radiation energy capture and use in photosynthesis. Similar results of increment in plant height with shade was observed by Lakshmamma and Rao (1996b) in blackgram and Hossain *et al.* (2017) and Nair (2020) in green gram under partially shaded coconut garden. Keuskamp *et al.* (2010) reported that since shading stimulates the synthesis of auxin and gibberellins, plants show increased height and etiolated leaves, as these hormones promotes cell division, cell elongation, apical dominance and inter nodal elongation. Increased plant height may be due to stimulating action of auxin which softens the cell wall by increasing its plasticity (Tagawa and Bonner, 1957) or may be the oxidative decarboxylation of synthetic auxins which could not be catalyzed by the enzyme peroxidase (Reincecke and Bandurski, 1987).

Number of leaves per plant also varied significantly among varieties under low light intensity at 1 MAS and at harvest. The varieties that grew taller at 1 MAS *viz*., DBGV 5, CO 6, Sumanjana, VBN 5 and VBN 6 produced a greater number of leaves. Attridge (1990) observed that low light intensity will promote a greater number of leaves to expose more photosynthetic area under limited illumination. At 2 MAS, significant difference in terms of number of leaves per plant was not evident among the varieties/cultures. This could be related to the attainment of peak flowering stage by all the varieties and cultures at around 50-60 days, leading to the utilization of photosynthates for reproductive growth rather than vegetative growth. The leaf production capacity and leaf persistence of all varieties and cultures were lower at the time of harvest. Lesser production of leaves could be due to the utilization of energy for flower and pod formation rather than vegetative growth. Lower production and persistence of leaves during harvest stage was also reported by Yamini (2019) in blackgram variety, CO 6 in open condition. Number of branches per plant varied initially and towards the later stage, much variation was not observed among the varieties and cultures under study. It could be endorsed to the lesser vegetative growth during the remaining growth period as well as increased influx of photosynthates to the reproductive parts (Deol *et al.*, 2018).

There was a remarkable variation in LAI at flowering among the blackgram varieties and cultures tested. Taller plants with more number of leaves at 50 per cent flowering resulted in a notable increase in LAI in both CO 6 and DBGV 5 recording 5.77 and 5.36 and least in TAU 1 (Fig. 6). Those varieties with tolerance to low light

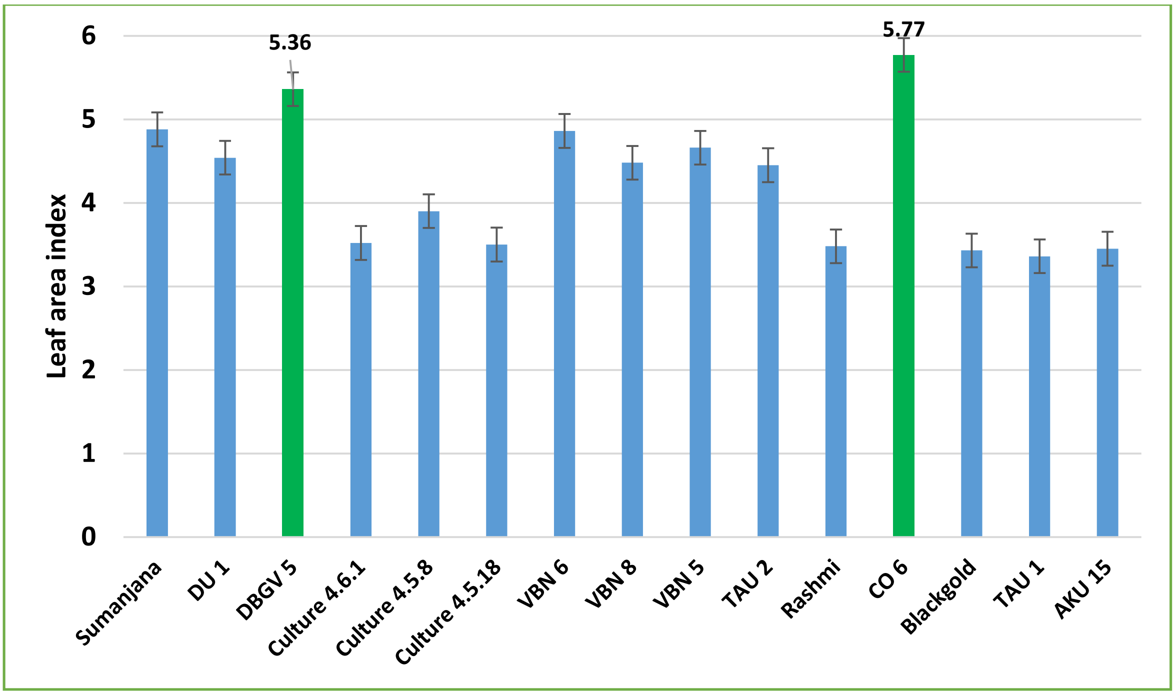

Fig. 6 Variation in leaf area index among blackgram varieties and cultures screened for shade tolerance in coconut garden

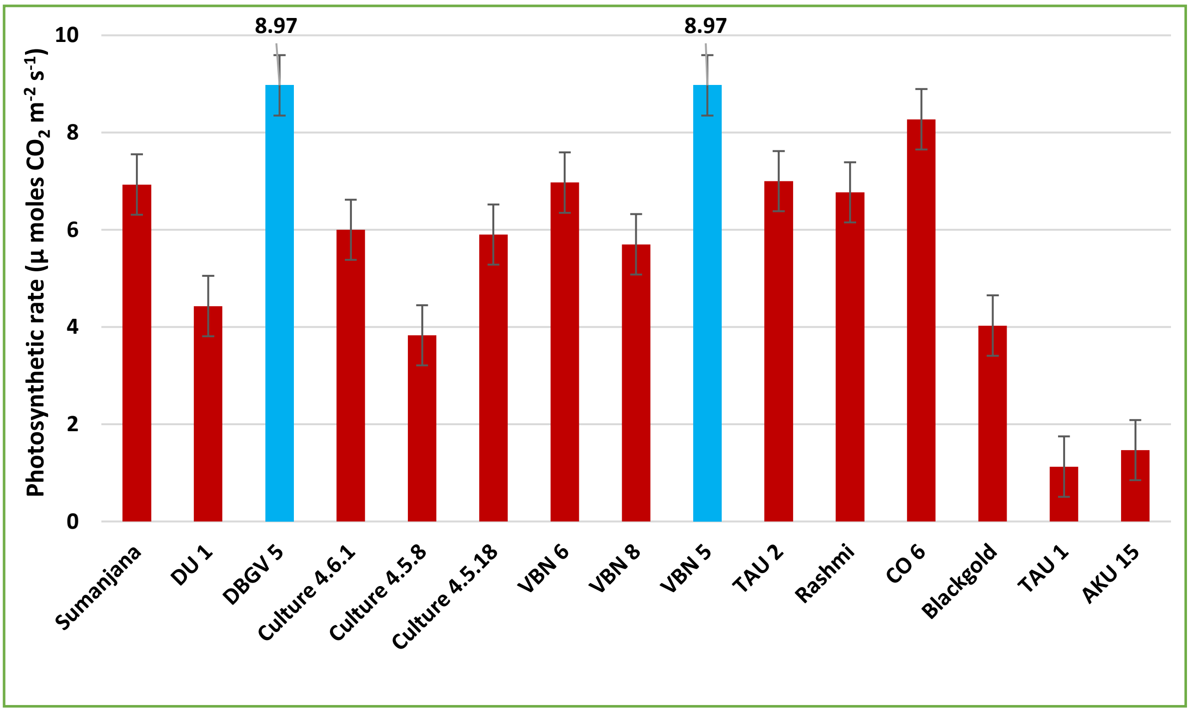

Fig. 7 Variation in photosynthetic rate among blackgram varieties and cultures screened for shade tolerance in coconut garden

intensity were found to develop more assimilatory area for high photosynthesis thereby contributing towards additional source activity. According to Fitter and Hay (1981), plants under the shaded condition adapt to low light intensity conditions by increasing the leaf area to obtain a larger surface for light absorption. This indicated that change in leaf morphology in response to shade maximized capture of the growth limiting resource (light) which is more extreme in shade adapted species (Lambers *et al.*, 1998).

5.1.2 Root Characters

The response of varieties and cultures on number and dry weight of nodules at flowering and root characters *viz.,* rooting length, root volume and dry weight of root at harvest were recorded and presented in Table 6 and 7. Root characters showed no significant variation among the varieties under low light intensity in coconut garden. Rao and Ghildiyal (1985) and Vidal *et al.* (1996) observed lower nodule activity under low light intensity compared to open condition. The root characters were comparatively higher under intercropped situation in the present study than under open condition as reported by Yamini, (2019) which could be due to the positive influence of other growth characters. It was in contrary to the results obtained by Wang *et al.* (2003) who reported that the root characters *viz.*, rooting length, root volume and root dry weight increased under high light intensity compared to low light.

5.1.3 Physiological Characters

The effect of varieties and cultures on physiological characters *viz.*, photosynthetic rate, leaf area duration (LAD), stomatal index, chlorophyll content and proline content were evaluated. There was significant variation in physiological and biochemical characters of varieties and cultures in response to low light intensity (Tables 8 and 9). The photosynthetic rate was superior for the varieties DBGV 5 and VBN 5 (Fig. 7) due to higher LAI at flowering and LAI is considered as an indicator of photosynthetic efficiency. It could be deducted that the light intensity in the interspaces was enough to drive the photosynthates and other vital physiological processes for these varieties *viz.*, DBGV 5, VBN 5, and Sumanjana and CO 6 indicating their tolerance to shaded situations.

Stomatal index was higher for the varieties DBGV 5, VBN 8, TAU 2 and Sumanjana at flowering. In general, abaxial surface possessed a greater number of stomata than adaxial to reduce transpiration loss (Kong *et al.*, 2016). Under shading stress, VBN 6, CO 6, VBN 5, DBGV 5 and Sumanjana recorded a greater number of stomata in the abaxial surface than adaxial compared to other varieties. However, increased persistence of leaf at flowering measured as leaf area duration (LAD) was realized in varieties, DBGV 5, CO 6, VBN 6 and Sumanjana which might have promoted more absorption of solar radiation (Fig. 8). Setiawati *et al.* (2018) reported that, species with higher stomatal index tend to be more responsive to the increase in CO_2, and hence the rate of photosynthesis will be greater. Higher LAI coupled with increased persistence of leaf might have enhanced PAR and thereby photosynthetic rate in varieties, DBGV 5 and VBN 5. In order to maximize the quantity of light absorbed and the quantum yield for CO_2 absorption during photosynthesis in the shade, the quantity of light absorbed and the quantum yield for CO_2 uptake must both be maximized (Hadi *et al.*, 2006). The varieties DBGV 5, VBN 5 and Sumanjana had adapted to low light intensity under coconut garden by increasing the LAI and LAD, thereby improving the photosynthetic rate t hus negating the effect of higher stomatal index, which otherwise might have contributed yield reduction. Yao *et al.* (2017) reported that, shade tolerant soybean cultivar L32 had increased PS II activity and energy transmission from PSII to PSI, as well as improved photosynthetic capacity and yield.

Significant variation in chlorophyll a, b and total chlorophyll contents were observed among the varieties and cultures under low light intensity. Chlorophyll a and total chlorophyll contents were higher for the variety DBGV 5 and was on par with

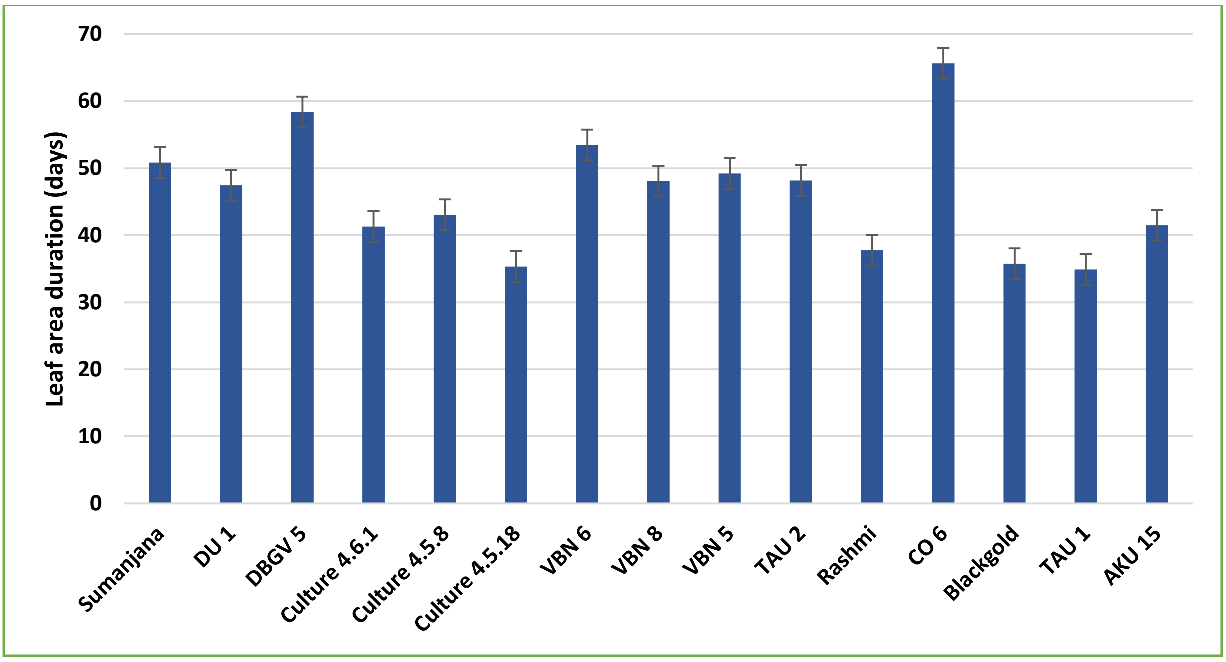

Fig. 8 Variation in leaf area duration among blackgram varieties and cultures screened for shade tolerance in coconut garden

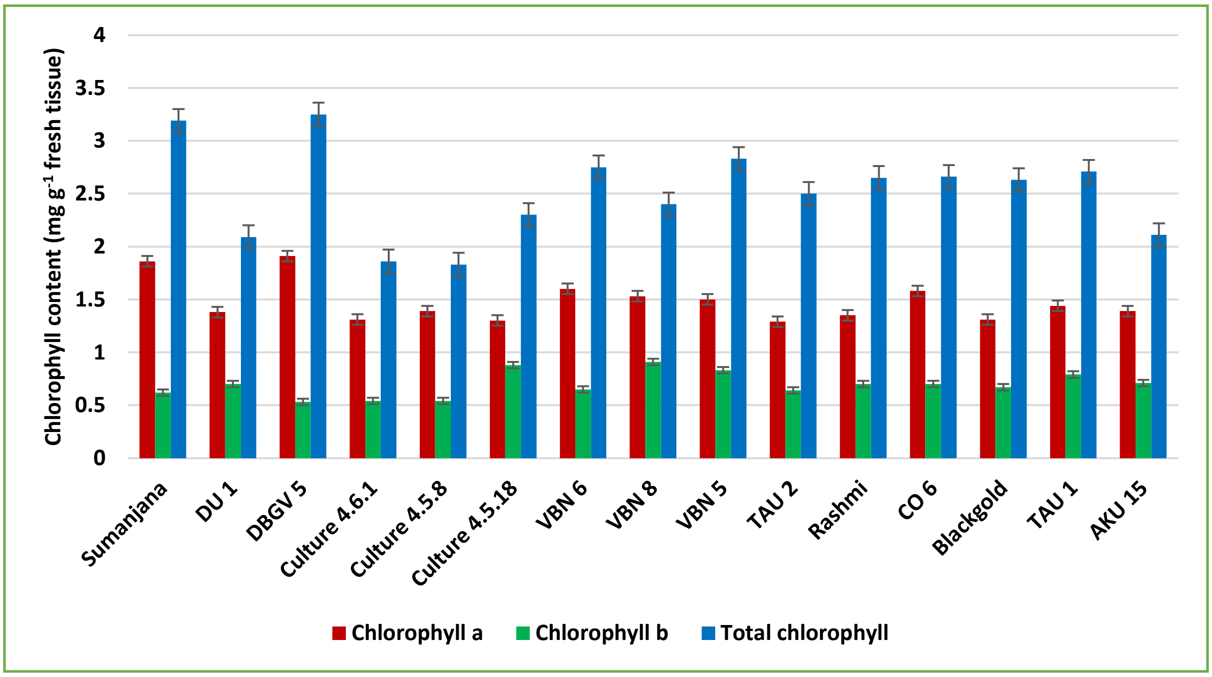

Fig. 9 Variation in chlorophyll content among blackgram varieties and cultures screened for shade tolerance in coconut garden

Sumanjana (Fig. 9). The increased content of chlorophyll in these varieties under shading stress might be to enable the plant to enhance the efficiency of light absorption indicating adaptation to low light intensity. Higher value of chlorophyll b was recorded by the varieties, VBN 8, VBN 5, TAU 1 and Culture 4.5.18. According to Watson and Dallwitz (1992), one of the ways to adjust low irradiation due to shade was an increase in leaf chlorophyll content. Higher chlorophyll content could be related to the increase of light harvesting complex (LHC II) and the enlargement of the antenna in photosystem II which resulted in increased light capture efficiency. In leaves of plants grown under lower light intensities, the plastid was limited in number arranged at right angles to the light rays and were larger in size thus increasing the area of light absorption (Zhang *et al.*, 2016). Araki *et al.* (2014) studied the impact of shading on growth and photosynthetic efficiency in green gram and reported that plants under shade treatment showed an increased amount of chlorophyll content per unit leaf area.

Proline is an enzyme produced in response to stress condition in plants and is considered as a defense mechanism in plants (Liang *et al.*, 2013). The blackgram varieties and cultures grown under low light intensity showed no significant variation in proline content. Further, the proline concentration was negligible (0.030-0.045 µ g g^{-1} of soil) compared to open condition, where proline concentration might go up to 70-200 µ g g^{-1} of soil (Geetha, 2004). This might be due to the lesser water stress under low light intensity, low evaporation and high soil moisture content. The finding highlights the suitability of blackgram in partially shaded coconut gardens, as the low light intensity was not a limiting (stress) factor under the given climatic and management practices considered in the study.

5.1.1 Yield Attributes and Yield

There was substantial difference among the varieties and cultures tested with respect to days to 50 per cent flowering, number of pods per plant, 100 seed weight and seed yield (Table 10). The variety Sumanjana and the Culture 4.6.1 and DBGV 5 flowered much early compared to other varieties with 34-36 days to reach 50 per cent flowering. The variety DBGV 5 produced the highest number of pods per plant and on par with Sumanjana, VBN 5, VBN 6 and CO 6 under shade. The length of pod and number of seeds per pod did not vary significantly under shade. However, hundred seed weight is an important yield determining character of each variety and culture. The Culture 4.6.1 produced bold seeds with the highest 100 seed weight and was at par with DBGV 5, DU 1, Blackgold, TAU 1 and AKU 15 under coconut garden.

Yield attributes are finally transformed into yield and the highest seed yield was recorded by DBGV 5. It was followed by VBN 5, Sumanjana, VBN 6, CO 6 and VBN 5 (Fig. 10). Increased yield in these varieties could be due to the higher number of pods per plant produced by the respective varieties. It is evident that these varieties were tolerant to shading stress and could be recommended as suitable for intercropping in coconut garden with a light intensity ranging from 40-46.5 klux as shade levels equivalent to 48-50 per cent of open condition. Sumanjana was earlier recommended for cultivation in southern (Thiruvananthapuram) Kerala (KAU, 2016). Interestingly, yield of VBN 5 was 109.65 per cent higher than the yield recorded under open condition while that of DBGV 5 and Sumanjana were 98.61 per cent and 97.18 per cent of the average yield recorded under open field conditions. It could be inferred that the light intensity levels in the interspaces in coconut gardens was sufficient to drive photosynthates and related physiological processes in shade tolerant varieties. The study distinctly identified DBGV 5 as the most tolerant blackgram variety for partial shaded situation in coconut garden

Higher seed yields realized in these varieties could be attributed to its better growth characters such as taller plants, more number of branches and leaves per plant, high leaf area index as well as physiological characters such as high total chlorophyll content, and higher photosynthetic rate. These attributes might have augmented source capacity and increased the sink activity. Seed yield of grain legume is generally related

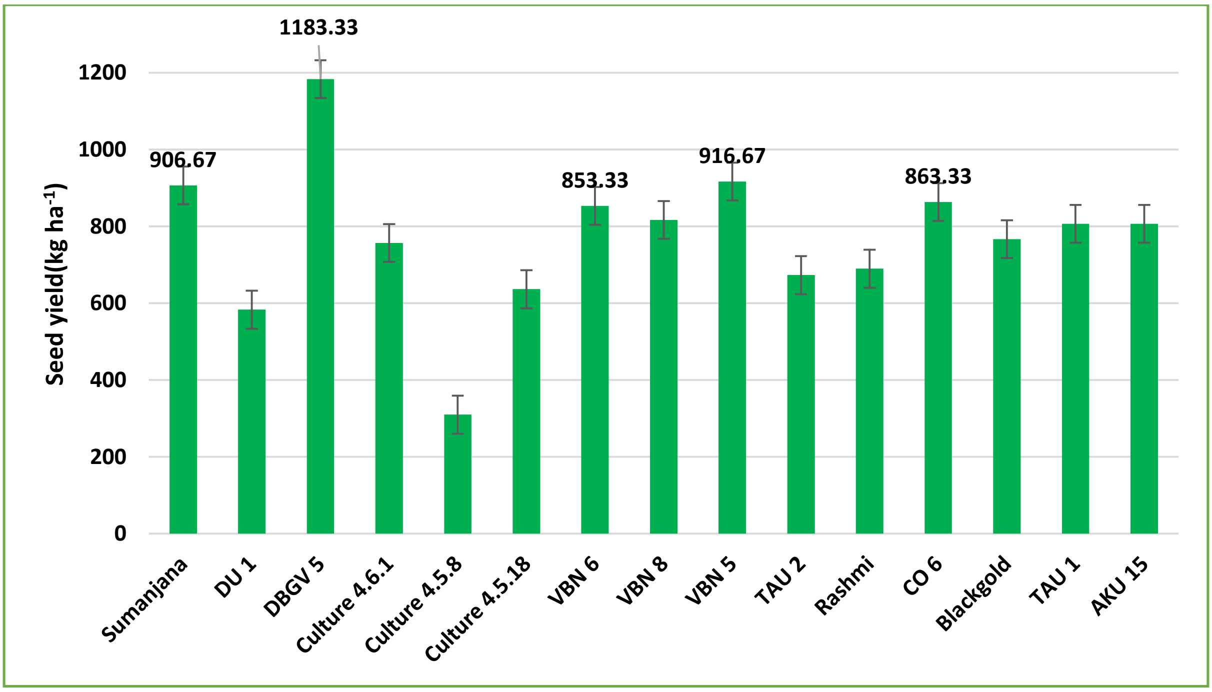

Fig. 10 Variation in seed yield among blackgram varieties and cultures screened for shade tolerance in coconut garden

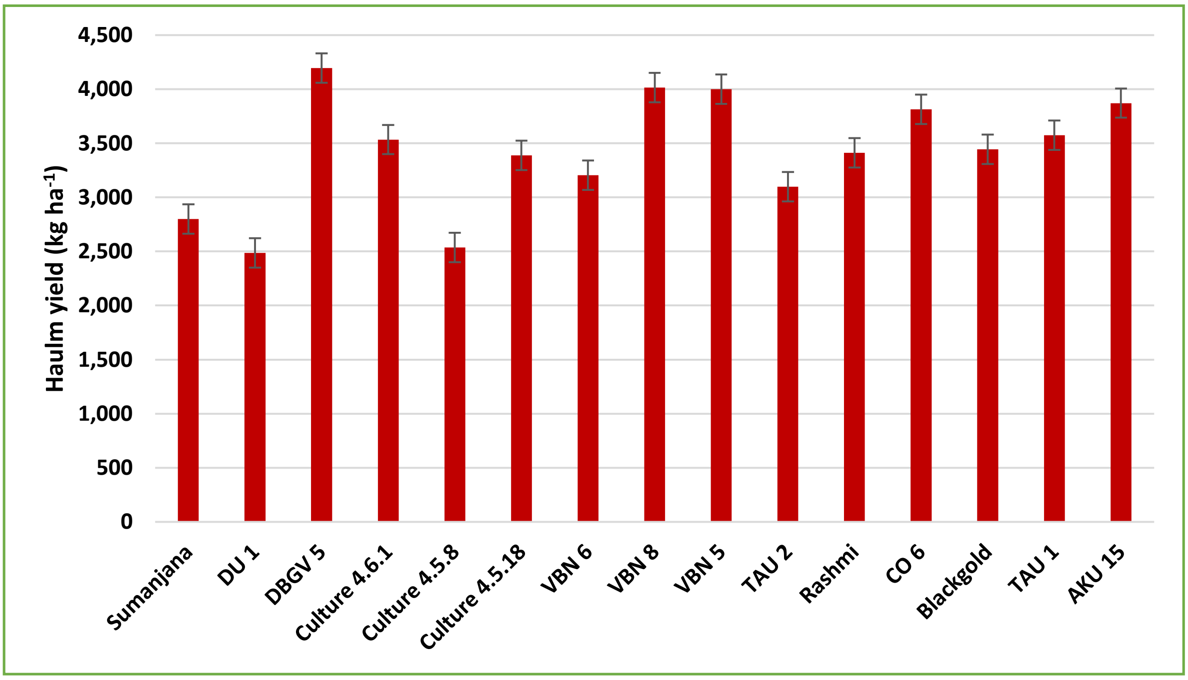

Fig. 11 Variation in haulm yield among blackgram varieties and cultures screened for shade tolerance in coconut garden

to physiological characters like leaf area index and photosynthetic efficiency [Johnson and Pendleton (1968) in soybean; Flinn and Pate (1970) in field peas]. As suggested by Chandrababu *et al.* (1985) in blackgram, leaf photosynthesis is one of the basic physiological attributes upon which plant biomass production depends. More influx of photosynthetic assimilates might have reached reproductive parts which ultimately resulted in the highest yield of blackgram variety DBGV 5 followed by VBN 5, Sumanjana, CO 6 and VBN 5. Hence it could be confirmed that leaf area index, total chlorophyll content and photosynthetic rate could be considered as indicators for shade tolerance in blackgram.

According to Lemaire *et al*. (2007) photosynthetically active radiation (PAR) has prodigious role in deciding the yield of a crop especially under low light intensity. Improved physiological characters like LAD, LAI, PAR and photosynthetic rate registered in these varieties might have resulted in superior seed yield under low light condition. Varieties and cultures varied significantly with respect to haulm yield also (Table 11). Higher haulm yield was produced by the varieties DBGV 5, VBN 5, Sumanjana and CO 6 (Fig. 11). The better performance in terms of seed and haulm yield of these varieties in coconut garden could largely be connected to its efficiency in capturing the solar radiation (55%) not intercepted by the canopy (Liyanage and Dassanayake, 1993). It could be inferred that DBGV 5, VBN 5, Sumanjana, CO 6 and VBN 6 could perform equally well under intercropped situations without unfavourably affecting the photosynthetic rate and finally yield.

Similar to seed yield, different varieties and cultures showed variability in dry matter partitioning and harvest (Table 12). Different PAR levels had substantial impact on the dry matter accumulation in the leaf, stem and pod, affecting the plant's overall dry matter output (Akhter *et al.,* 2016). In the present study, the varieties DBGV 5, VBN 5 and Sumanjana had more assimilates in the reproductive parts (Fig. 12) than the vegetative parts, which contributed towards higher seed yield. However, the highest leaf dry weight realized in Culture 4.5.8 was manifested as the lowest seed yield among all the varieties evaluated under the study. Consequently, it produced the lowest seed yield among all the varieties and cultures under study. The added effect of vegetative and reproductive parts resulted in variation in total dry matter production with higher value registered by the varieties AKU 15, VBN 8, VBN 5 and DBGV 5. Harvest index, an important parameter in deciding the yield of crop also varied significantly and the varieties Sumanjana, DBGV 5 and VBN 6 recorded higher harvest index (Fig. 13). Though the haulm yield recorded was greater in Sumanjana and DBGV 5, the higher seed yield in these varieties might have caused the harvest index in the range of 0.23-0.24. But in other varieties and cultures, the seed yield was proportionately lower compared to haulm yield thereby reducing the harvest index. Seed yield of green gram was improved as a result of maintaining a relatively high total dry matter output while simultaneously improving the harvest index. (Natarajan and Palanisamy, 1988). This could be due to better partitioning of source to sink, leading to transportation and accumulation of more photosynthates to growing reproductive parts rather than vegetative parts (Manoj *et al.*, 2019).

5.2 PERFORMANCE EVALUATION OF SHADE TOLERANT VARIETIES OF BLACKGRAM UNDER FOLIAR APPLICATION OF NUTRIENTS AND GROWTH REGULATORS IN RAINFED COCONUT GARDEN

Blackgram is a short duration pulse crop that survives better in all seasons either as sole crop, intercrop or catch crop. In experiment II, the performance of shade tolerant blackgram varieties identified were evaluated for their response to different sources of foliar nutrients and plant growth regulators (PGR). The results of the experiment revealed the significant influence of varieties, foliar application of nutrients and plant growth regulators under partial shade in rainfed coconut garden during both the seasons *viz.*, summer 2020 and *Rabi* 2020-21. The results of two seasons are discussed hereunder.

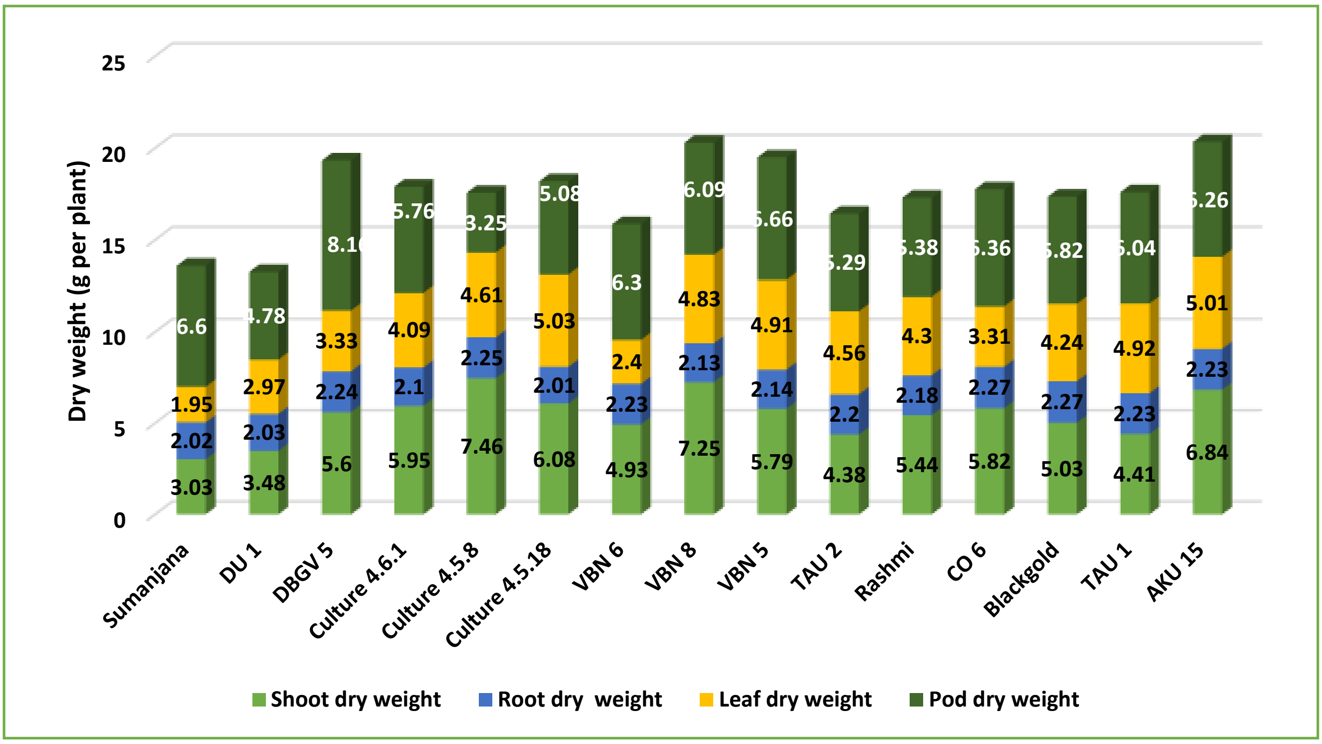

Fig. 12 Dry matter partitioning of blackgram varieties and cultures screened for shade tolerance in coconut garden

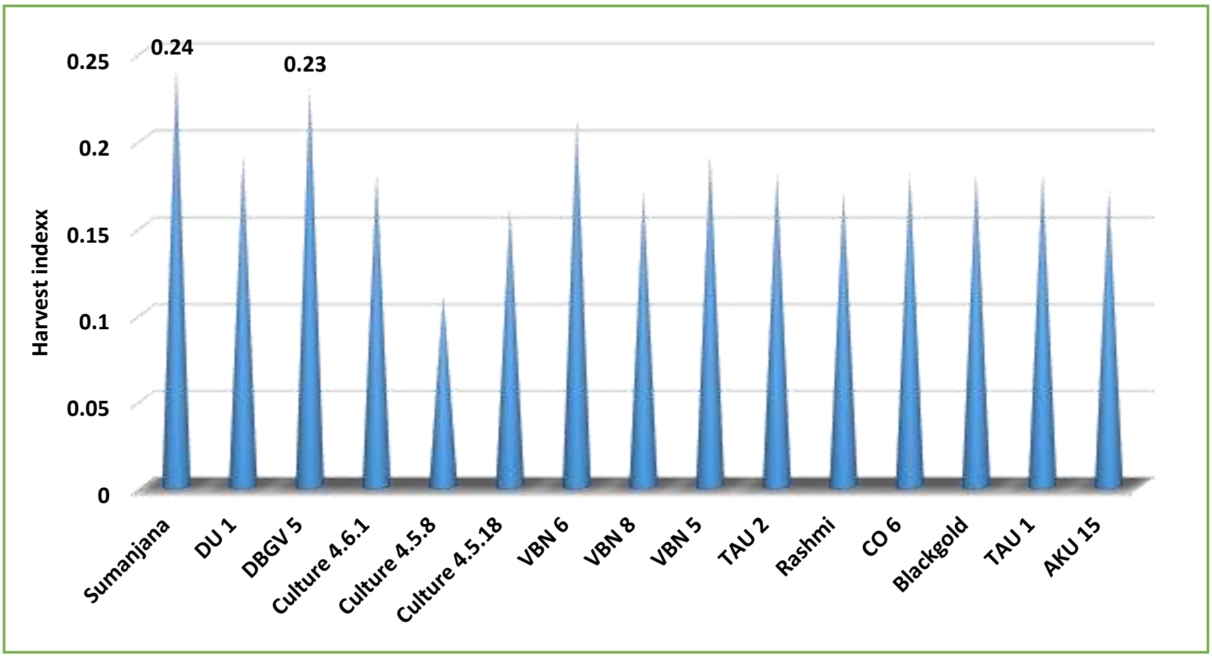

Fig. 13 Variation in harvest index among blackgram varieties and cultures screened for shade tolerance in coconut garden

5.2.1 Growth Characters

The growth characters *viz.*, plant height, number of leaves per plant, number of branches per plant at monthly interval and LAI at flowering varied significantly due to varieties and foliar application of nutrients and plant growth regulators under partial shade in rainfed coconut garden. The study revealed that varieties responded differently to shading stress in terms of morpho-physiology and yield. The variation in varietal performance might be attributed to its genetic factors (Poehlman, 1991). In general, plant height and number of branches per plant showed an increasing trend upto harvest in all the varieties under partial shade. However, the number of leaves per plant peaked up at 2 MAS and showed a declining trend towards harvest in all the treatments. Among the varieties, Sumanjana grew taller than other varieties during *Rabi* with comparable heights as that of CO 6 at 1 MAS and DBGV 5 at 2 MAS. However, during summer Sumanjana was the tallest upto 1 MAS and later comparable with CO 6 at harvest. In general, plants adapted to low light intensity grow taller producing longer internodes resulting in increased plant height. The ability to grow taller under shading stress by Sumanjana, CO 6 and DBGV 5 could be inferred as their ability for shade adaptation so as to optimize photosynthesis under partial shade. Lower light intensity reduces the photo-oxidation of auxin which promotes cell division in the apical meristem (Muller and Basch, 2021). Increased height of these varieties indicated the adaptation to capture more solar energy for photosynthesis under partial shade in coconut garden.

Foliar spray of nutrients and plant growth regulators had significant effect on plant height at 2 MAS and at harvest (summer) and the tallest plants with greater number of branches and leaves per plant were produced with the foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4). This might be due to the supplementation of primary nutrients (N, P and K) as 19:19:19 along with plant growth regulators through the foliage, which helped to increase the source activity *viz.*, plant height, number of branches per plant and number of leaves per plant. Foliar spray of NAA helps in rapid increase in cell division and cell elongation in the meristematic region thereby producing taller plants with a greater number of branches and leaves (Swamy *et al.*, 2021). The results are in congruence with the reports of Singh *et al.* (2009), Pathak *et al.* (2012) and Ganga *et al.* (2014).

The combinations of varieties and foliar sprays *viz*., Sumanjana (v_1) or CO 6 (v_5) supplied with 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4 and v_5f_4) produced significantly taller plants during summer and *Rabi* (v_1f_4). It could be deduced that the varieties Sumanjana and CO 6 responded well to foliar spray under shade in terms of plant height. The variation in plant height among varieties might be due to its genetic characters attributing tolerance to shaded condition in coconut garden. Foliar application of nutrients and PGRs enhanced tissue differentiation and expansion, resulting in taller plants with greater number of leaves per plant by rapid absorption of nutrients in the shaded situation (Shwetha *et al.*, 2021).

Number of branches per plant varied significantly during the summer season with higher number of branches in Sumanjana and CO 6 throughout the crop growth. The number branches produced by plants was in line with the plant height and taller varieties produced a more number of branches. Sumanjana supplied with 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) produced more number of leaves per plant during both the seasons at all growth stages. This could be attributed to the positive interaction between plant height and number of branches by the respective variety.

Leaf area index is the measure of leafiness of the crop in relation to land area. In general, LAI was higher during summer compared to *Rabi* season. Plants adapt to shading stress by increasing leaf area expansion for maximizing light interception. The varieties Sumanjana and CO 6 recorded higher values of LAI during both the seasons, which could be ascribed to the higher number of leaves recorded in these varieties. Higher leaf area is an adaptation to capture irradiance more efficiently under shaded situation for tolerant varieties, which could contribute to better photosynthesis. Sumanjana and CO 6 were found to be shade adaptive with higher LAI to compensate shade induced reduction in photosynthesis. Foliar application of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded the highest LAI. Foliar spray significantly influenced the leaf production and plants fertilized with all major nutrients and PGR were superior with respect to LAI, during both the seasons which can be ascribed to the enhanced availability of nutrients from readily soluble fertilizers. Grindlay (1997) reported that N availability is essential to enhance the leaf area and to maintain the leaf longevity. Growth promoting substances such as NAA at 20 ppm had a positive effect on cell division and cell elongation leading to enhanced leaf expansion (Girisha, 2010).

Regarding the interaction effects of varieties and foliar sprays, Sumanjana supplied with 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) recorded higher LAI and was on par with v_5f_3 and v_5f_5 during summer season (Fig.14a). In the *Rabi* season, the treatment combination v_1f_4, v_2f_4 and v_3f_4 were on par (Fig.14b). Foliar application of fertilizers and PGRs increased the number of leaves and branches per plant which might have contributed to higher LAI and improved photosynthetic efficiency. These results are in accordance with the findings of Venkatesh and Basu (2011) in chickpea, Sarker and Rahim (2013), Das and Jana (2015) in lentil and Dey *et al.* (2017) in mung bean. Higher LAI might be attributed to the active role of auxins in enhancement of cell division and cell elongation (Upadhyay and Ranjan, 2015). The positive influence of foliar spray of nutrients through mineral fertilizers could enhance availability and in turn promote cell division and cell elongation and consequent crop growth and development. Similar findings were reported by Cheghakhor *et al.* (2009) and Ali and Mohmoud (2013).

The number of nodules per plant was higher during *Rabi* season compared to summer season. Nodule formation is influenced by soil and environmental factors and low temperature during *Rabi* compared to summer might have increased the activity of the nod gene in *Rhizobium* and accelerated the process of symbiotic nitrogen fixation thereby increased the number of nodules during *Rabi.* Al-Falih (2002) also reported increased nodulation at low temperature in different legumes. Among the varieties, Sumanjana and CO 6 produced more number and dry weight of nodules during summer while during *Rabi*, DBGV 5 proved superior. Foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in the highest number and dry weight of nodules per plant at flowering during both the seasons. Barik *et al.* (1994) also reported increase in number of nodules with foliar application of nutrients. This might be due to the prominent supply of growth hormones and other nutrients owing to the growing tip of root establishment activity throughout the growth period (Karthikeyan *et al.*, 2020). In the case of interaction effects, the treatment combination v_1f_4 produced more number and dry weight of nodules per plant at flowering and was on par with v_2f_4 and v_5f_4 during summer and the treatment combinations v_1f_4 and v_5f_4 produced higher number and dry weight of nodules per plant during *Rabi*. The increase in number of nodules per plant with foliar application could be attributed to role of nutrients in enhancing plant vigour and strengthening the stalk as reported by Ester and Gautam, (2020).

5.2.2 Root Characters

There was no significant difference in root characters *viz.*, rooting length and root volume due to varieties, foliar sprays and their interaction during both the seasons. However, root dry weight showed significant variation due to the individual effects during *Rabi* season. Better moisture availability during *Rabi* season might have increased the root thickness rather than length as observed in summer.

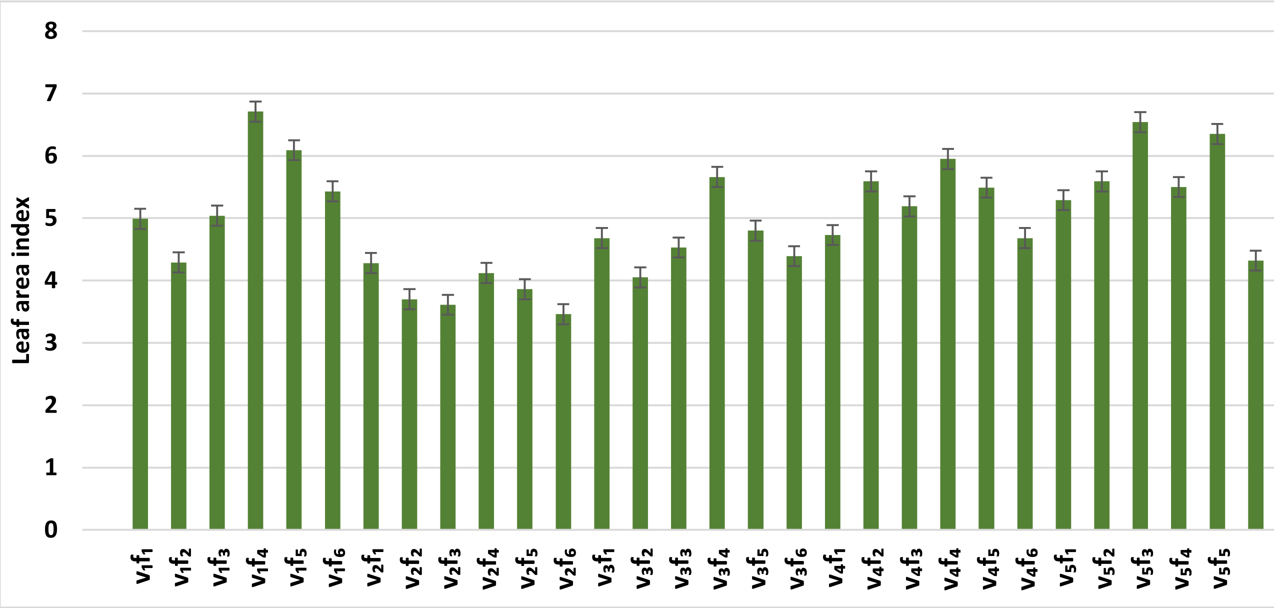

Fig. 14a Interaction effect of varieties and foliar spray on leaf area index during summer 2020

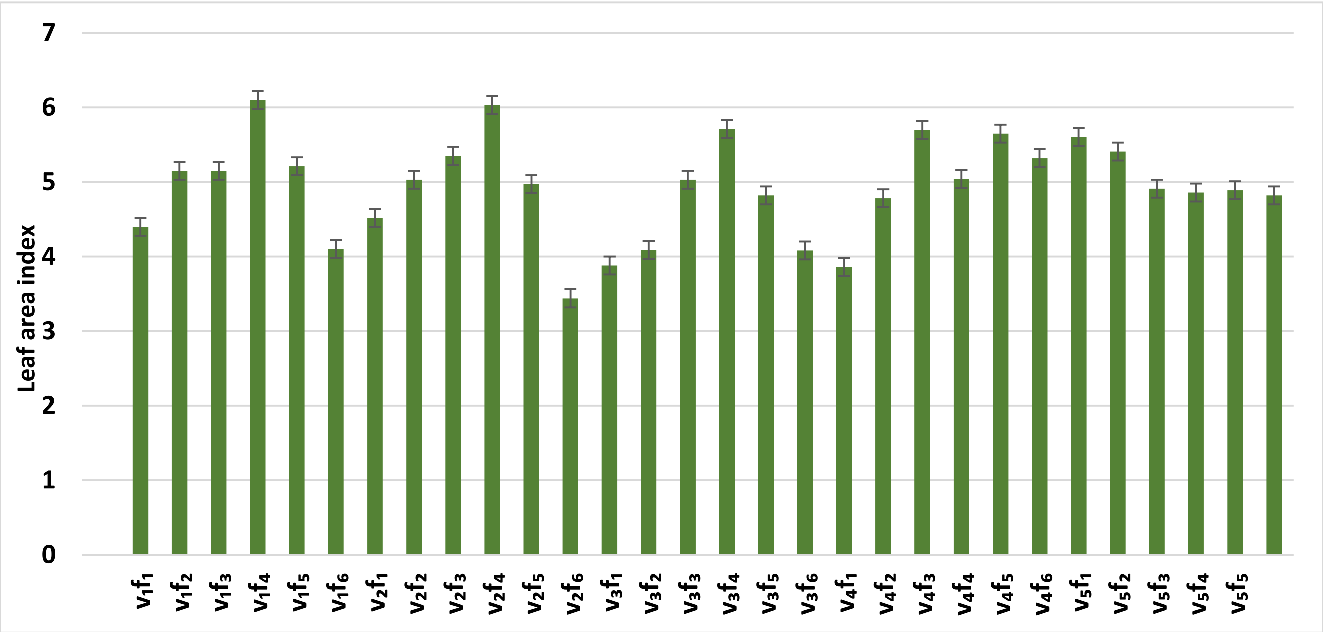

Fig. 14b Interaction effect of varieties and foliar spray on leaf area index during *Rabi* 2020-21

Among the main plot factors, Sumanjana recorded the highest root dry weight, and among the subplots f_4 produced the highest root dry weight. This can be correlated with the higher root dry weight observed in f_4 due to foliar spray of nutrients and growth regulators. However, the interaction effect was not significant in both the seasons. Effect of foliar spray of NAA in increasing root dry weight was reported by Wang and Deng (1992), and Durrani *et al.* (2010) and Thakre *et al*. (2013).

5.2.3 Physiological Characters

Physiological parameters are used to determine the changes in growth of crop in relation to time and is a function of light interception of the crop canopy and influenced by LAI, photosynthetic rate and leaf angle. Interaction of phytohormones and nutrients on growth and development of crop plants cause positive responses on plant growth rate (Mir *et al.*, 2010).

Crop growth rate (CGR) is the rate of dry matter accumulation per unit land area per unit time in crop stands. It is considered as a useful growth parameter for estimating the production efficiency of a crop. In the present study, comparatively lower CGR values were computed during the initial growth stage (30-45 DAS) which could be accounted as early development stage of the crop. Crop growth rate was found to rise later and peaked at 45-60 DAS coinciding with the stage of flowering to pod development and thereafter it declined towards maturity. The trend remained similar during both the seasons. Crop growth rate depends on radiation use efficiency, which is the amount of intercepted photosynthetically active radiation and the efficiency of the crop to convert intercepted photosynthetic active radiation to above ground biomass (Cirilo *et al.,* 2009).

Among the main plot treatments, CGR varied significantly with Sumanjana having higher dry matter production per unit area or net primary productivity followed by DBGV 5, during all the growth stages. Among the subplot factors, f_4 recorded higher

CGR at 30-45 DAS and 45-60 DAS and towards maturity (between 60-75 DAS) and f_3 recorded the highest CGR during both the seasons (Fig. 15a and 15b). In another study in green gram, (Singh and Jambukiya, 2020) illustrated higher CGR at 30-45 DAS and at 45-60 DAS with the combined application of nutrients and PGRs. The interaction effect is the cumulative effect of main and subplot effect and the treatment combination v_1f_4 recorded the highest value of CGR during both the seasons. This could be ascribed to the positive interaction of individual effects as described above.

Relative growth rate (RGR) determines the increase in plant dry matter over a time interval in relation to initial dry weight (Tajul *et al.,* 2013). The value of RGR was higher initially and towards harvest, it declined gradually during both the seasons due to decline in CGR as well as decline in the rate of dry matter production. A similar trend was reported by Arun *et al.* (2017) in cowpea. Between 30-45 DAS, VBN 5 recorded higher RGR during both the seasons. However, during the peak period of the crop growth, *i.e.*, between 45-60 DAS, Sumanjana recorded the highest RGR and towards harvest, while the varieties DBGV 5 and VBN 5 recorded higher values during summer and *Rabi* respectively. In the case of subplot factor, f_3 and f_4 recorded comparatively higher RGR in all the growth stages. This could be due to the positive influence of foliar spray of nutrients and PGRs on cell division and cell elongation, which facilitated better crop growth and development resulting in higher growth characters. It could be inferred that compared to soil application, foliar nutrition had the advantages of rapid uptake, availability and utilization resulting in enhanced dry matter accumulation over time. Foliar application delay onset of leaf senescence through improved photosynthetic efficiency as a result of higher nutrient uptake and thereby increasing the RGR (Yadav and Choudhary, 2012). Among the treatment combinations, v_1f_4 recorded higher RGR values between 30-45 DAS and later it declined. The decrease in RGR was probably due to the increase in metabolically active tissues than meristematic tissues at further stages of crop, which contributed less to the plant growth (Biswas *et al.,* 2002); (Hussain *et al.,* 2011). This has been explained by

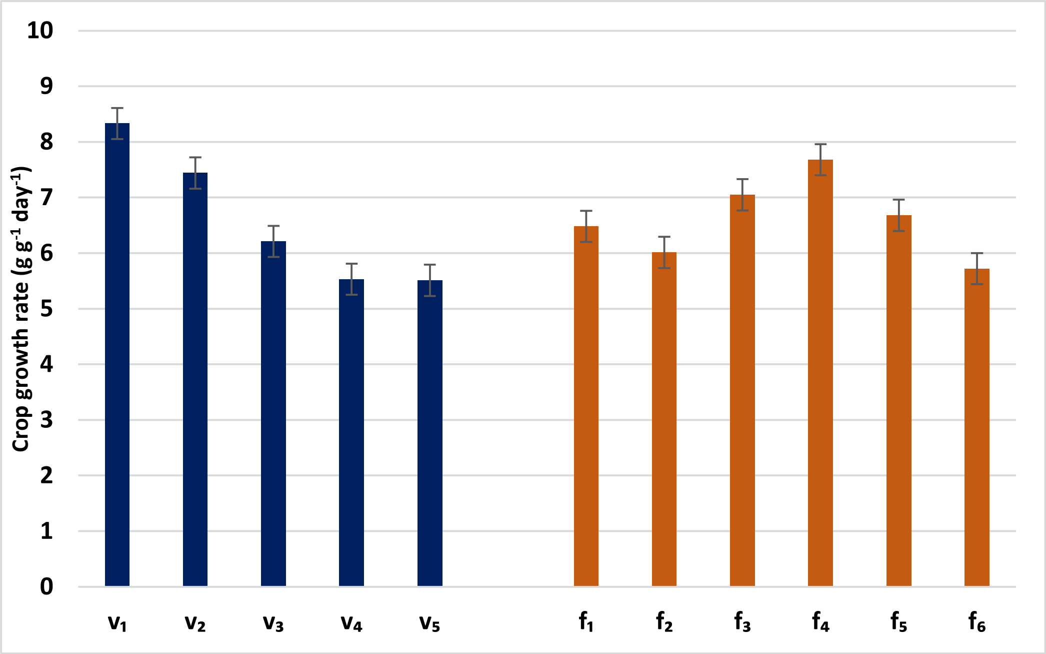

Fig. 15a Interaction effect of varieties and foliar spray on crop growth rate (45-60 DAS) during summer 2020

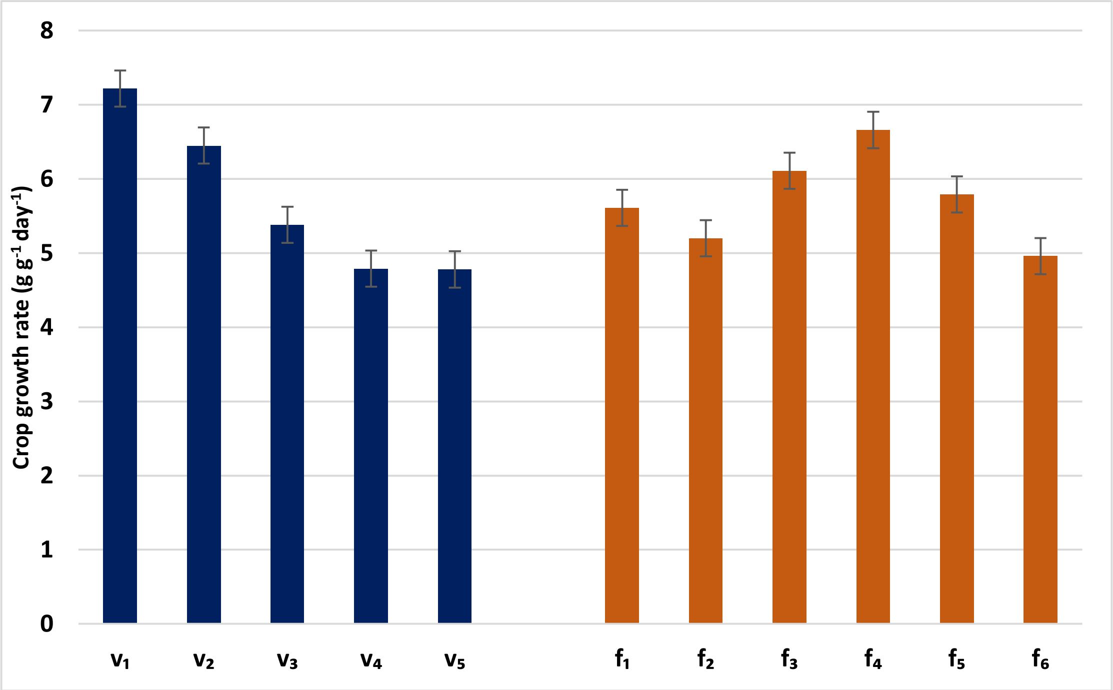

Fig. 15b Effect of varieties and foliar spray on crop growth rate (45-60 DAS) during *Rabi* 2020-21

Benincasa (2003) that, as plant organs develop and the plant approaches the physiological maturity, organ demands for photo assimilates for their own maintenance increases, reducing the photo assimilate availability for extra growth.

Net assimilation rate (NAR) is a measure of the average photosynthetic efficiency of leaves in a crop community (Vernon and Allison, 1963). The variety DBGV 5 recorded higher NAR during both the seasons between 30-45 DAS which indicated the higher assimilatory capacity of the variety under shaded situation. Regarding the subplot factor, there was no significant difference in NAR between 30-45 DAS during both the seasons. Between 45-60 DAS, NAR showed significant difference in the summer season only and higher NAR was recorded due to the foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_3) and was on par with f_4 and f_5. A positive response to foliar spray was elicited as increased dry matter accumulation per unit leaf area and was reflected as higher NAR. However, NAR exhibited no significant variation at any of the growth stages due to interaction effect during both the seasons.

Specific leaf weight (SLW) is the measure of leaf weight to leaf area and it indirectly relates the production of photo assimilates. Higher SLW indicates more leaf thickness or density. At 30 DAS, the highest value of SLW was recorded by VBN 5 during both the seasons and later, Sumanjana recorded higher SLW. There was significant difference in SLW due to foliar spray at all the stages and f_4 recorded higher values at 30, 45 and 75 DAS. At 45, 60 and 75 DAS, the highest SLW was recorded in v_1f_4 during all the stages in summer and *Rabi* seasons. Plants that grow in a shady environment invest relatively more of the products of photosynthesis and other resources in leaf area and leaf weight to increase light harvesting and photosynthetic surface (Lambers *et al.,* 1998). It has been shown that plants grown under shade, produced leaves with a higher SLW and allocate more nitrogen in leaves to light harvesting, thereby optimizing light interception and carbon assimilation per unit biomass of leaf (Evans and Pooter, 2001; Lambers *et al.*, 2008). This was contradictory to the reports of decreasing SLW over increasing LAI.

Chlorophyll is cardinal for photosynthesis and are present in the chloroplasts. Nutrients being the constituents of various metabolites like chlorophyll, enzymes and hormones influence various physiological processes which in turn affect the growth and productivity of crops (Maurya *et al.*, 2014). The varieties DBGV 5 and Sumanjana recorded higher chlorophyll content at flowering. This might be because of the fact that leaves under shade have higher chlorophyll concentration per unit of fresh mass. Kulsum *et al.* (2007) observed that with the increasing N levels in blackgram, leaf chlorophyll and nitrogen content increased linearly. The subplot factor f_4 recorded higher chlorophyll content during both the seasons. The increased absorption and translocation of nutrients through foliar application might have enhanced the chlorophyll synthesis and photosynthetic activity. The increase in chlorophyll content reflects increased PS II photochemistry, photosynthates production and dry matter accumulation. Maity and Bera (2009) illustrated that foliar application of salicylic acid influenced different physiological and biochemical aspects of green gram plant via increasing assimilation rate which revealed increase in chlorophyll content and hill reaction activity in the leaf. Khandker *et al.* (2015) observed increased chlorophyll content due to application of NAA. The treatment combination v_1f_4 recorded the highest chlorophyll that can augment the rate of photosynthesis for better accumulation of photoassimilates.

Stomatal index is the number of stomata compared to total number of epidermal cells expressed in percentage. Crops with lower stomatal index are preferred as they reduce transpiration rate and improve photosynthetic rate to the optimum. Sumanjana recorded the lowest stomatal index during both the seasons (Fig. 16a and 16b) which could be inferred as a more efficient investment in photosynthetic machinery. Foliar spray significantly influenced stomatal index and foliar spray of 19:19:19 (1%) at 45

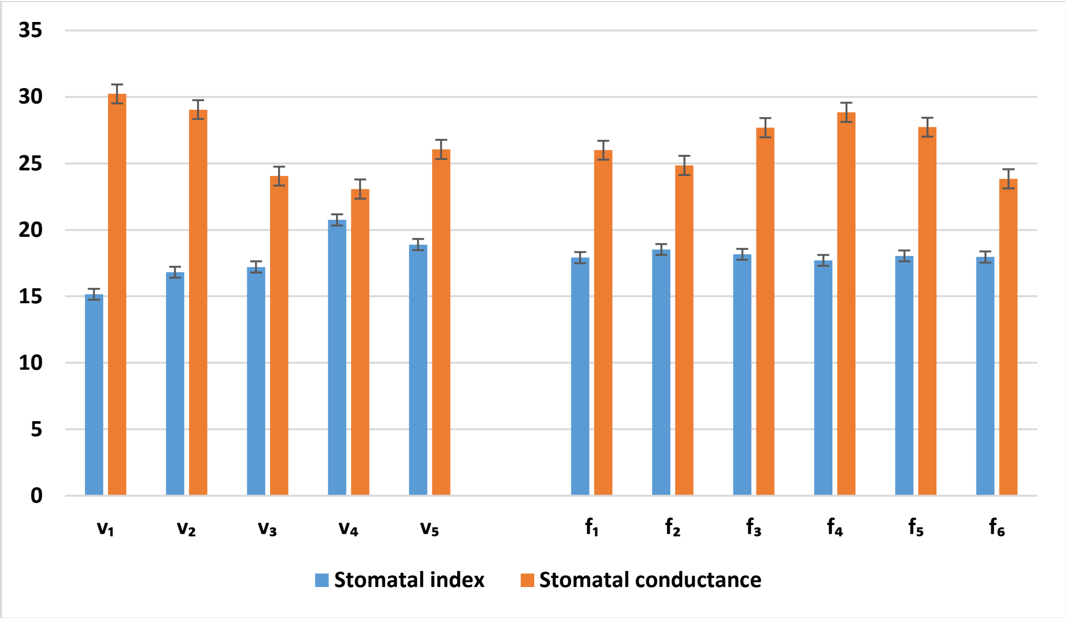

Fig. 16a Effect of varieties and foliar spray on stomatal index and stomatal conductance during summer 2020

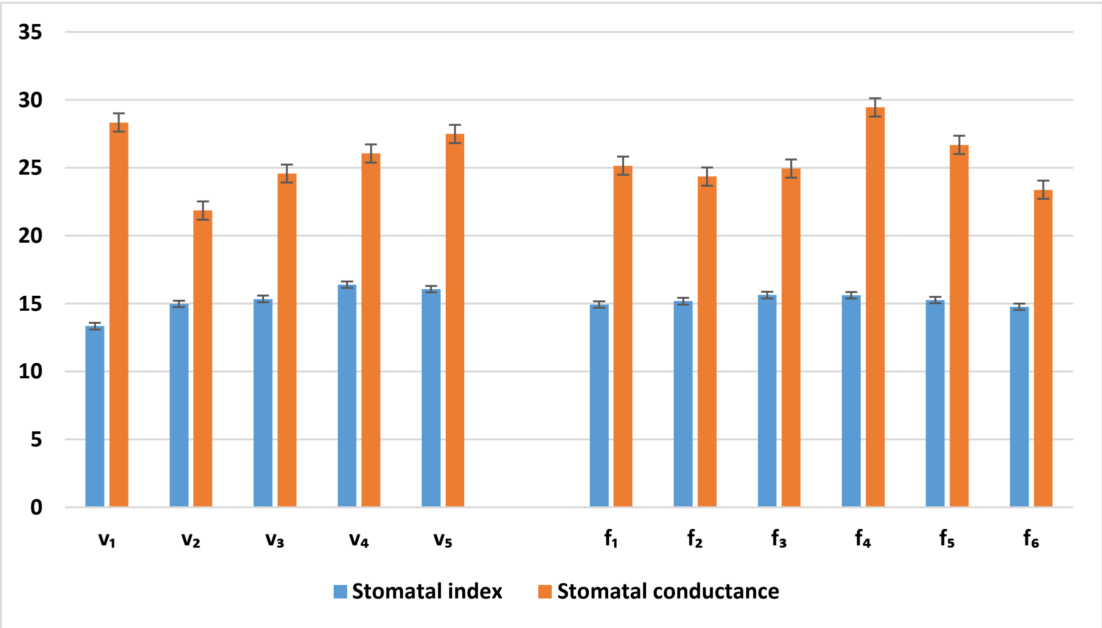

Fig. 16b Effect of varieties and foliar spray on stomatal index and stomatal conductance during *Rabi* 2020-21

and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded lower stomatal index in summer. This could be related to the effect of foliar spray of salicylic acid which could change the balance of endogenous hormones and thereby induce stomatal closure and reducing transpiration rate and improving photosynthetic capacity (Hao *et al.*, 2011). The lower stomatal index was recorded in v_1f_4 and was on par with v_1f_3 and v_1f_5. Similar results of lower stomatal index due to foliar spray of NAA was also reported by Jahan and Yasmin (2017).

Stomatal conductance is the ability of stomata for gaseous exchange. During both the seasons, Sumanjana recorded the highest stomatal conductance (Fig. 16a and 16b) at flowering indicating a higher gas exchange without significant loss of photosynthetic productivity enabling the plants to express their genetic potential. Foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in higher stomatal conductance during both the seasons. Increased stomatal conductance with foliar spray of salicylic acid was earlier reported by Khan *et al.* (2010). The main plot and subplot effect was reflected in interaction with v_1f_4 having the highest stomatal conductance during both the seasons. The content of soluble protein was unaffected due to main effects and interaction effects during both the seasons. However, the content was higher during the summer season compared to *Rabi* season.

5.2.4 Yield Attributes and Yield

The yield of a crop is governed by source activity, translocation and accumulation in sink apart from the genes in its genome (Howlader *et al*., 2018). Yield is dependent upon the sum total of crop growth and development and is the cumulative expression of different yield attributes (Kaur *et al.,* 2015). The yield attributing characters *viz.,* number of pods per plant and 100 seed weight varied due to varieties, foliar sprays and their interaction during both the seasons. Foliar applied nutrients and

PGRs will penetrate through leaf cuticle or stomata for easy and fast absorption into the cell (Latha and Nadanassababady, 2003) and modify the sink size and thereby affecting the yield.

Sumanjana showed earliness in flowering compared to other varieties during both the seasons followed by DBGV 5. Gardner *et al.* (1988) reported that floral induction occured in response to a specific number of favourable photo induction cycles, and it varied with plant species and varieties. The difference observed in days to 50 per cent flowering between two varieties could be attributed to their inherent characteristics. Similar observations were documented by Gangaiah and Ahlawat (2008) and Rao (2011) in chickpea and red gram respectively. Among the foliar sprays, NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_3) produced flowers earlier and was on par with f_5 in the summer season (Fig. 17a). During *Rabi*, the treatments, f_3, f_4 and f_5 took lesser days to attain 50 per cent flowering and was on par with each other (Fig. 17b). Das and Prasad (2003) observed that two sprays of NAA at 20 or 40 mg L^{-1} significantly reduced days to 50 per cent flowering. The interaction effect was the cumulative effect of main and subplot effects and the treatment combination v_1f_3 recorded the lowest number of days to attain 50 per cent flowering. Kothule *et al.* (2003) found that foliar application of NAA and salicylic acid each at 100 and 200 ppm and urea at 1 and 2 per cent reduced the number of days to 50 per cent flowering in soybean.

Sumanjana recorded the highest number pods per plant followed by DBGV 5 during both the seasons, at harvest. This indicated a higher degree of shade acclimation of these two varieties. The subplot factor also affected the number pods per plant and foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded the highest number of pods per plant during both the seasons. The role of NAA in lowering flower drop and enhancing flower set might be one of the reasons for higher number of pods per plant.

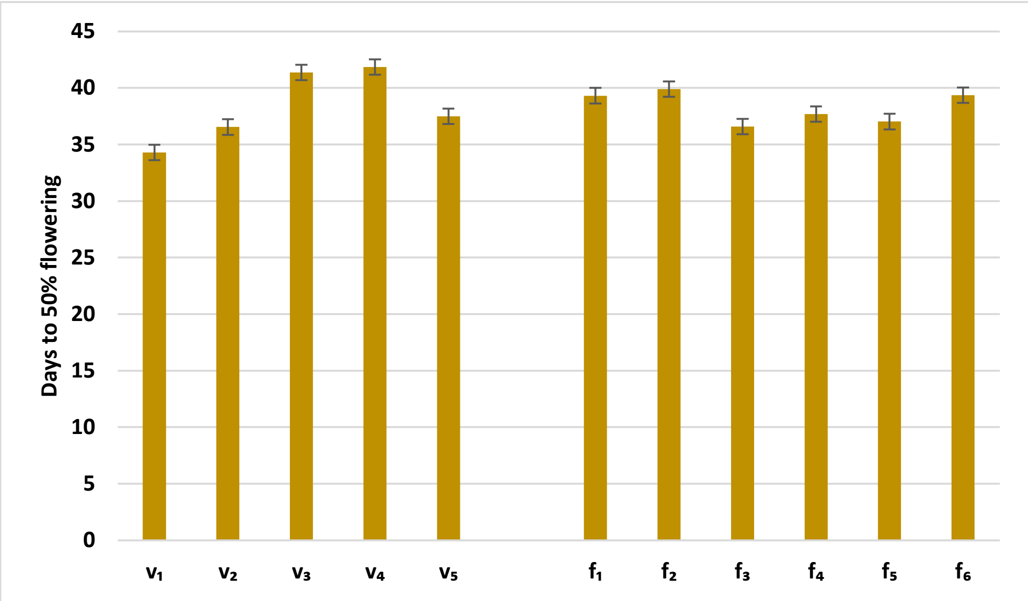

Fig. 17a Effect of varieties and foliar spray on days to 50% flowering during summer 2020

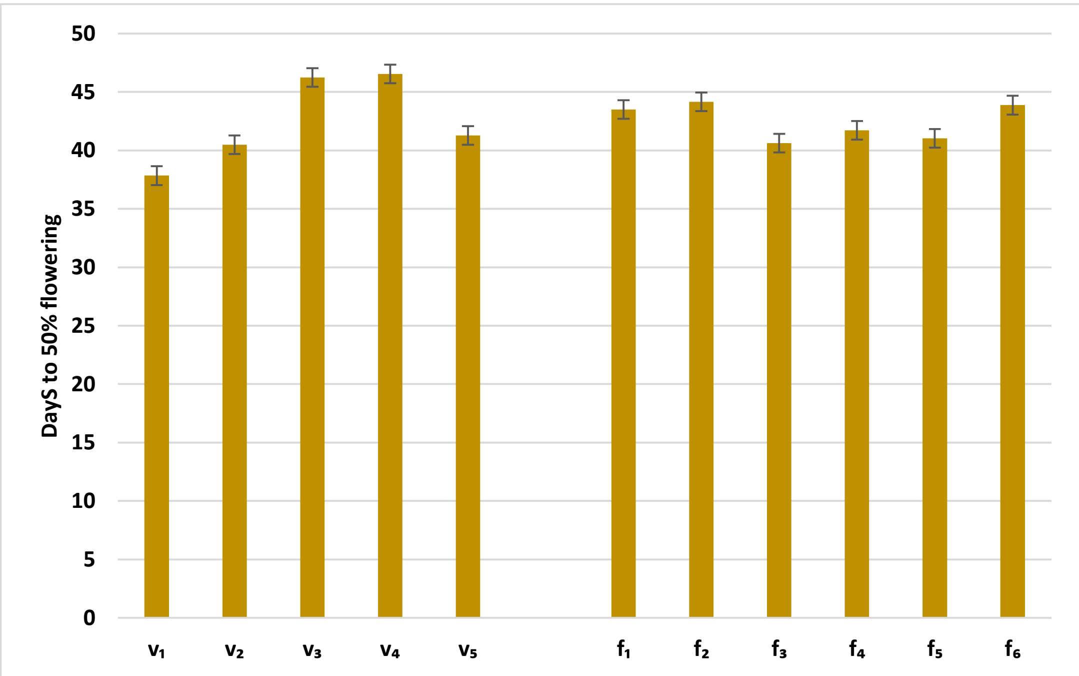

Fig. 17b Effect of varieties and foliar spray on days to 50% flowering during *Rabi* 2020-21

Further, at the initial growth stages, the foliage applied N, P and K (water soluble NPK 19:19:19) coupled with growth regulators might have been effectively absorbed and translocated to the pods resulting in a more number of pods per plant. Among the treatment combinations, Sumanjana under f_4 recorded the highest number of pods per plant during both the seasons (Fig. 18a and 18b). Foliar spray of nutrients modified the source sink relationship and increased the translocation and photosynthetic efficiency resulting in increased flower retention and pod set per cent (Ganapathy *et al.,* 2008) and reduced flower drop (Ravindranath *et al.,* 1985). Advanced supply of all nutrients at flower initiation and pod formation stages of crop growth might have caused efficient translocation of photosynthates from source to sink (Kumar *et al.,* 2018). Solaiappan *et al.* (2002) also reported similar finding in red gram.

Hundred seed weight showed significant difference during both the seasons. Sumanjana and DBGV 5 produced bold seeds with higher 100 seed weight and were on par with each other during both the seasons. Regarding the subplot treatments, foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded the highest 100 seed weight in summer and *Rabi* seasons. The treatment combinations v_1f_4, v_1f_5 and v_2f_4 realised higher values of 100 seed weight during both the seasons.

The cumulative effect of yield attributing characters was reflected finally in the yield and it varied significantly among the varieties during both the seasons. The varieties Sumanjana and DBGV 5 recorded higher seed yield per plant during both the seasons. Bhagwat *et al.* (2018) reported significant difference in the seed yield of various genotypes of blackgram. The foliar spray also significantly affected the seed yield per plant and foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in the highest seed yield per plant, during both the seasons. The control treatment as per KAU package was having the lowest seed yield per plant during both the seasons. The lowest seed yield recorded in control was due to lower dry matter production, lesser nodulation and lesser uptake and also due to the production of lesser number of pods per plant.

Among the treatment combinations, higher seed yield per plant was produced by Sumanjana and DBGV 5 along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (Fig. 19a and 19b). The increase in numbers of pods and pod yield per plant could be due to the export of nutrients at critical stage in balanced form (*i.e.* flowering and fruit setting) coupled with greater flower retention triggered by growth regulators. Abundance of nitrogenous fertilizers for photosynthesis ultimately enhanced utilization of photosynthates and increased allocation of photosynthates towards the economic part (Batra *et al.*, 2002). The findings of Karpagam *et al.* (2004) and Choudhary and Yadav (2011) are in confirmation with the present result. Sarkar *et al. (*2021) documented that foliar fertilization is best suited for *Rabi* pulses rather than top dressing or placement of fertilizers.

The individual effects of varieties, foliar nutrition and their combination revealed significant variation in haulm yield per plant during both the seasons. Sumanjana and DBGV 5 recorded higher haulm yield per plant during both the seasons. The highest haulm yield per plant was recorded with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) during both the seasons. Regarding the interaction effects, the treatment combination v_1f_4 recorded higher haulm yield per plant and was on par with v_2f_4 during both the seasons. Better canopy development for radiation interception by these varieties coupled with balanced fertilization could contribute to higher haulm yield.

Sumanjana and DBGV 5 recorded higher seed and haulm yield ha^{-1} during both the seasons. The subplot treatment of foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later

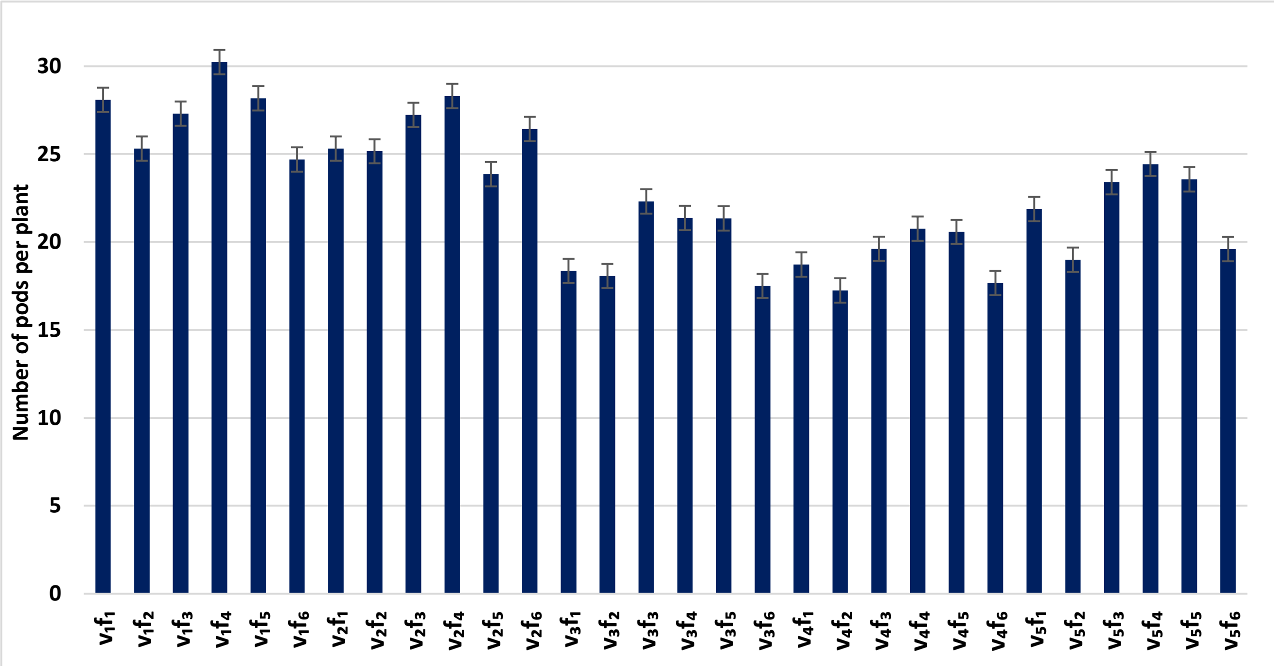

Fig. 18a Interaction effect of varieties and foliar spray on number of pods per plant during summer 2020

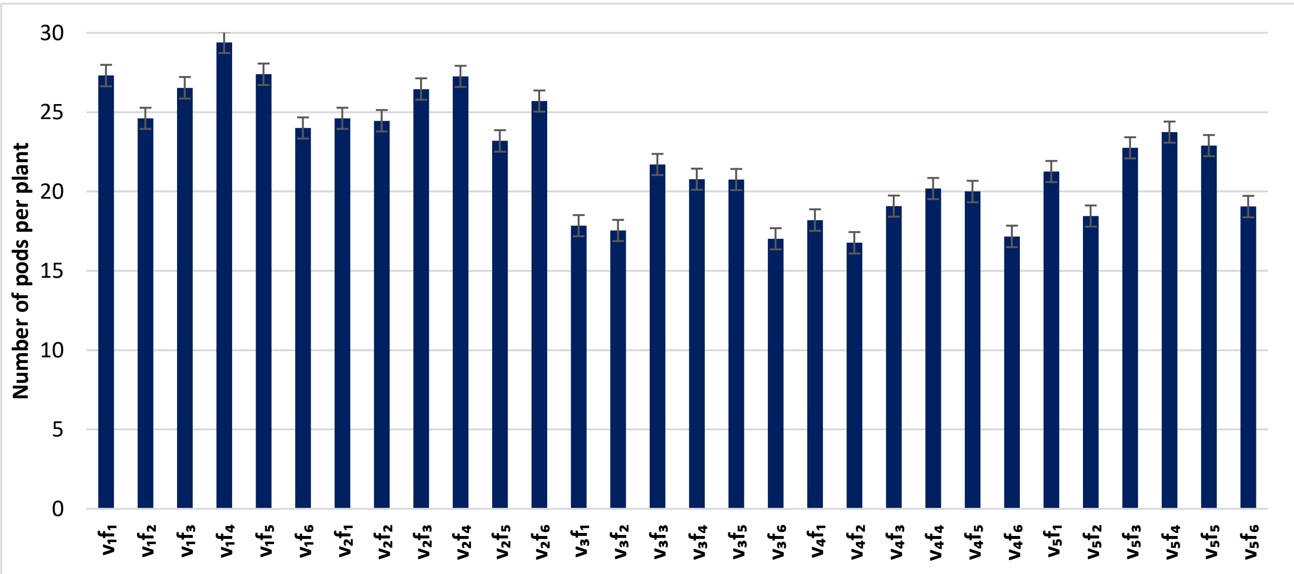

Fig. 18b Interaction effect of varieties and foliar spray on number of pods per plant during *Rabi* 2020-21

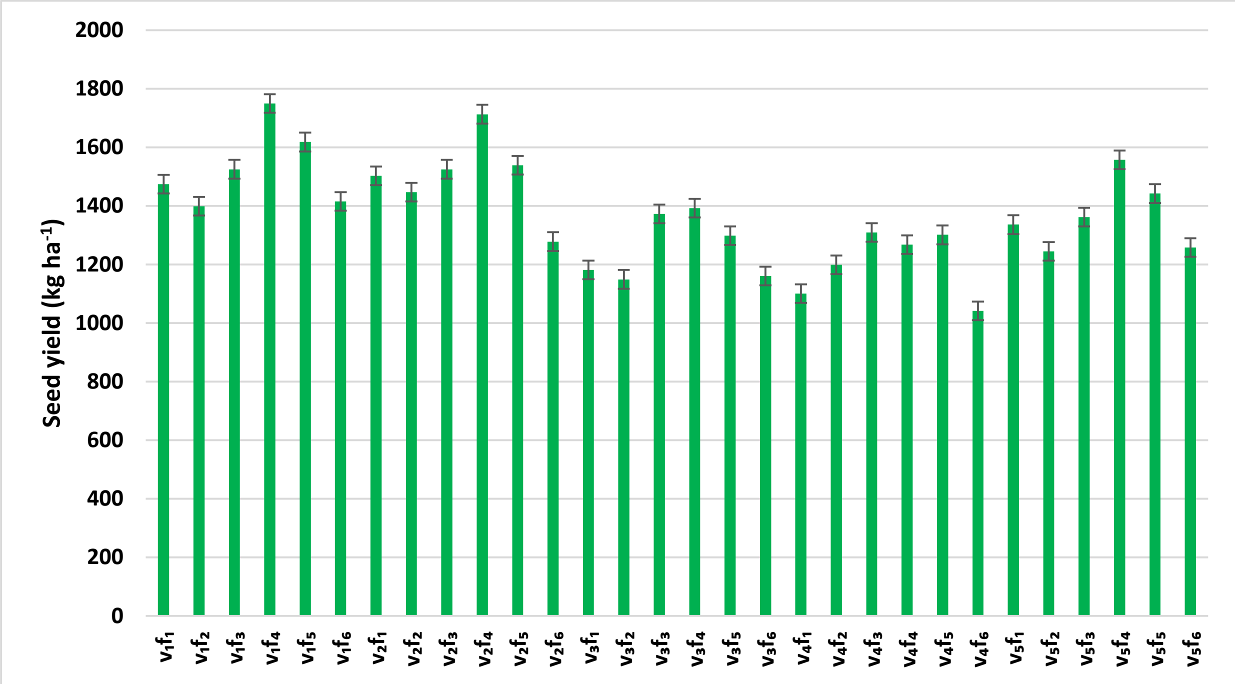

Fig. 19a Interaction effect of varieties and foliar spray on seed yield during summer 2020

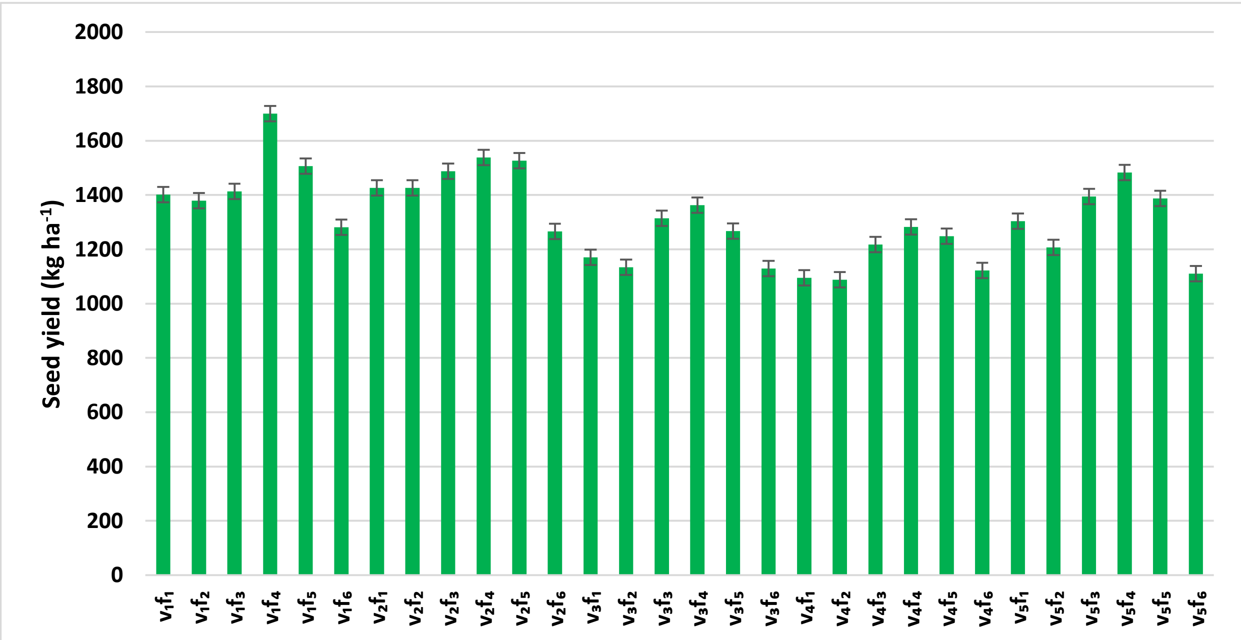

Fig. 19b Interaction effect of varieties and foliar spray on seed yield during *Rabi* 2020-21

(f_4) revealed the highest seed yield ha^{-1} during both the seasons. It was deduced that application of NAA negated flower drop which was manifested as increased pods per plant, 100 grain weight and seed yield in these two shade adaptive varieties. Foliar spray of salicylic acid can increase sink strength *via* cell division in the immature ovaries and conducts the metabolites stream to the developing grains which reduce the abortion rate (Horvath *et al*. 2007). Reducing the abortion rate could have significantly increased the number pods per plant and number of seeds per pod in soybean as observed by Khatun *et al.* (2016). Increased seed yield of pulse with foliar application of nutrients could be attributed to reduced flower drop and increased pod set percentage (Mamthashree, 2014). Main and subplot effects were reflected in the interaction, and higher seed and haulm yield were recorded in Sumanjana along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) and was on par with DBGV 5 along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_2f_4) in the summer season. During *Rabi* season, the highest seed and haulm yield was recorded in v_1f_4 followed by v_2f_4 (Fig. 20a and 20b). Foliar nutrients usually penetrate the leaf cuticle or stomata and enter the cells facilitating the easy entry of nutrients. Foliar application is credited with remarkably rapid absorption and nearly complete utilization of nutrients, elimination of leaching losses and fixation and helps in regulating the uptake of nutrient by plants (Manonmani and Srimathi, 2009). Upadhyay *et al*. (1993) and Shukla *et al*. (1997) documented that spray of growth regulators enhanced the number of pods per plant, seed yield per plant. This might be attributed to fulfilment of the demand of the crop by higher assimilation and translocation of phosynthates from source (leaves) to sink (pods) through the supply of required nutrients by foliar spray of 19:19:19. These results are in corroboration with the findings of Kuttimani and Velayutham (2011).

Pooled analysis on seed yield revealed Sumanjana and DBGV 5 to be better performers under partial shade with seed yield of 1489 kg ha^{-1} and 1473 kg ha^{-1}

respectively. The subplot factor f_4 recorded the highest seed yield (1505 kg ha^{-1}). The combination of main and subplot factors as v_1f_4 recorded the highest seed yield (1725 kg ha^{-1}) followed by v_2f_4 (1626 kg ha^{-1}) which is deduced to be due to the positive interaction of individual effects as explained above (Fig. 21). On comparison with KAU Package, Sumanjana and DBGV 5 under foliar spray of nutrients and PGR evinced 21.84 and 21.76 per cent increase in seed yield over v_1f_6 and v_2f_6 respectively (Fig. 22). Higher LAI and chlorophyll content observed in these treatments might have improved the photosynthetic activity leading to the production of more amount of carbohydrates and translocation of assimilates from source to sink which finally contributed to higher seed yield. Also, higher number of nodules and nodule mass observed in these treatments could have enhanced the assimilation, production of proteins and translocation of carbohydrate from source to sink which might have led to the production of higher number of pods per plant which in turn enhanced the seed yield per plant and seed yield ha^{-1}. Better crop growth enhanced the absorption of nutrients through root and enhanced the synthesis of IAA, carbohydrate and N metabolism which ultimately led to higher economic yield. The production of higher seed yield due to nutrients and growth regulators could be attributed to the fact that plants treated with macro nutrients and growth regulators remained physiologically more active to build up sufficient food reserves for the developing flowers and seeds.

Among the varieties, Sumanjana recorded higher total dry matter production (TDMP) and was on par with DBGV 5 during both the seasons. There was significant difference TDMP due to foliar spray during both the seasons. The highest TDMP was recorded with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) in summer and *Rabi* season. The treatment combination v_1f_4 and v_2f_4 were on par during summer season. During *Rabi* season, the highest TDMP was recorded in the treatment combination v_1f_4. Higher LAI and chlorophyll content observed in v_1f_4 might have enhanced the rate of photosynthesis which ultimately increased the dry matter

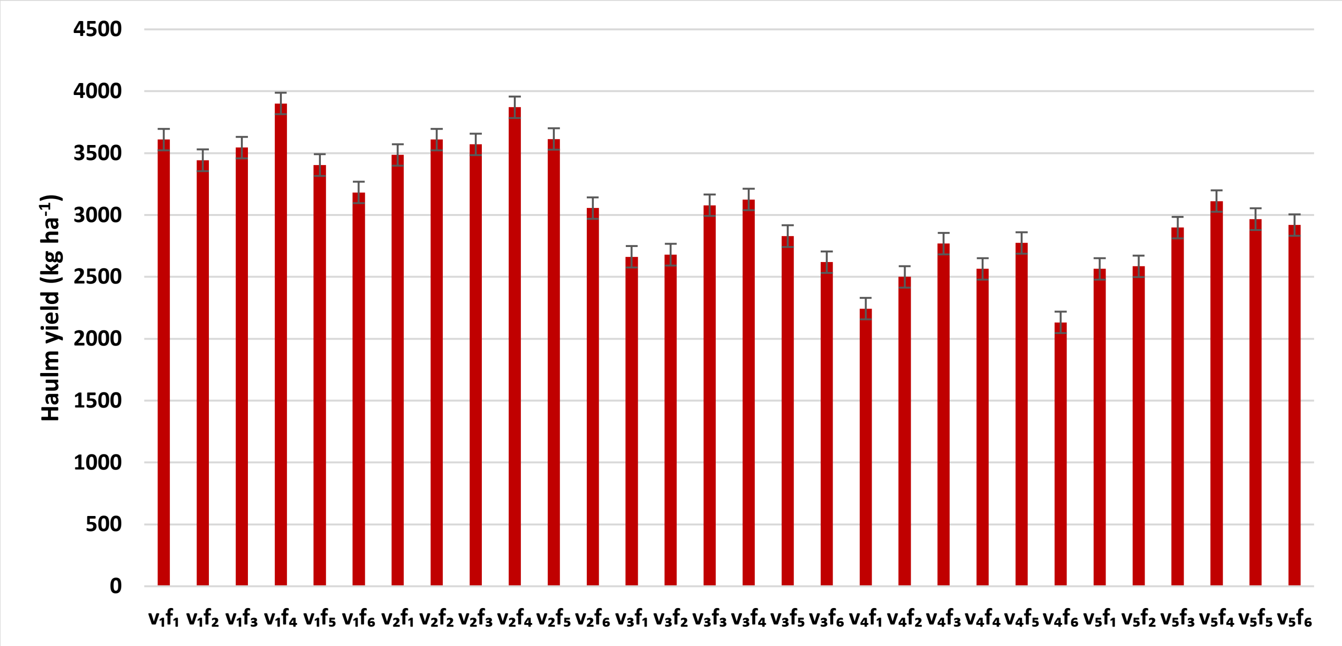

Fig. 20a Interaction effect of varieties and foliar spray on haulm yield during summer 2020

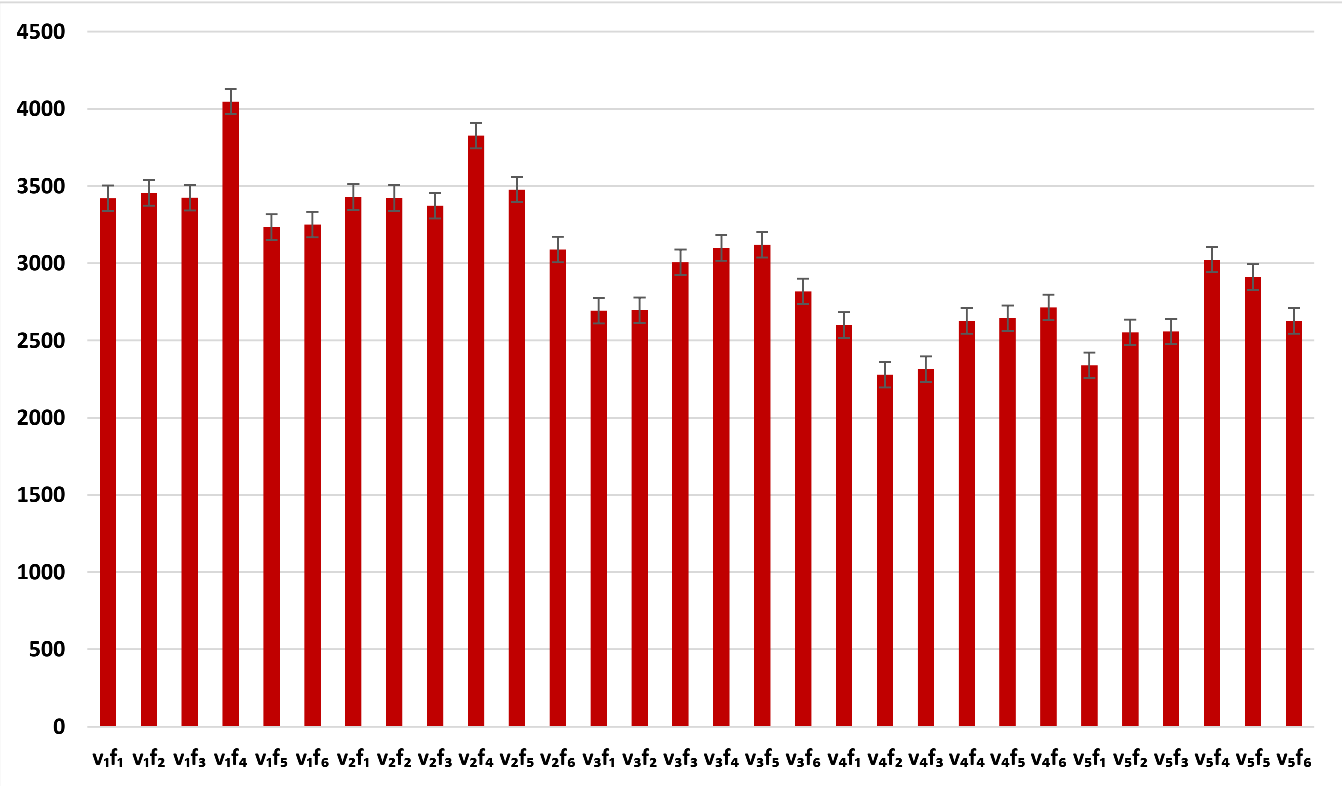

Fig. 20b Interaction effect of varieties and foliar spray on haulm yield during *Rabi* 2020-21

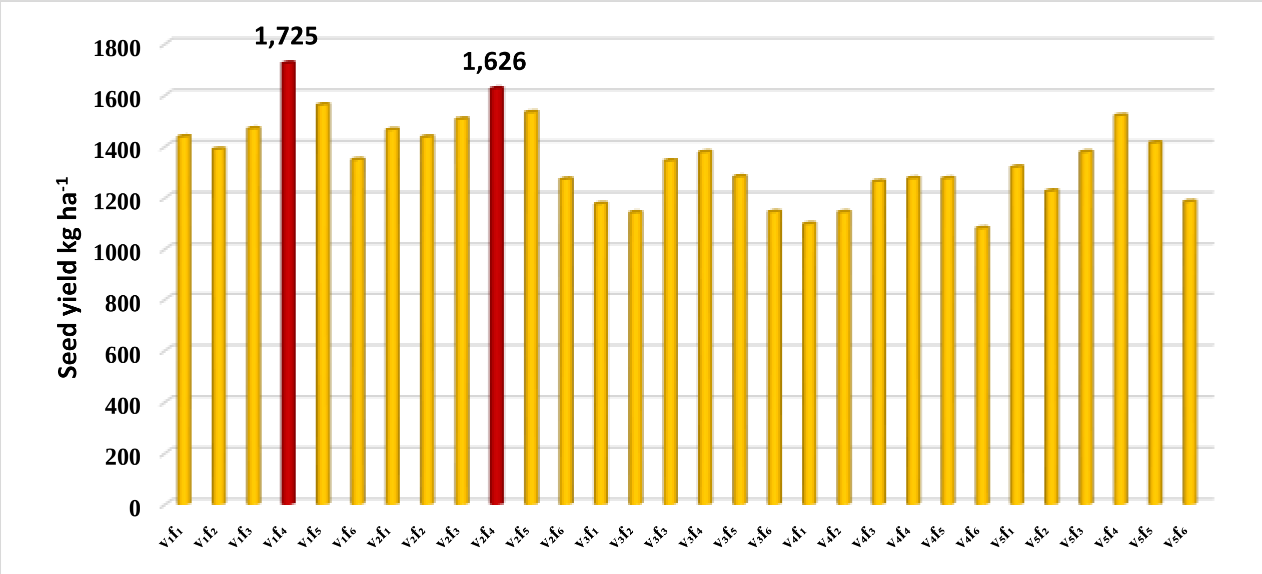

Fig. 21 Interaction effect of varieties and foliar spray of nutrients and plant growth regulator on pooled seed yield

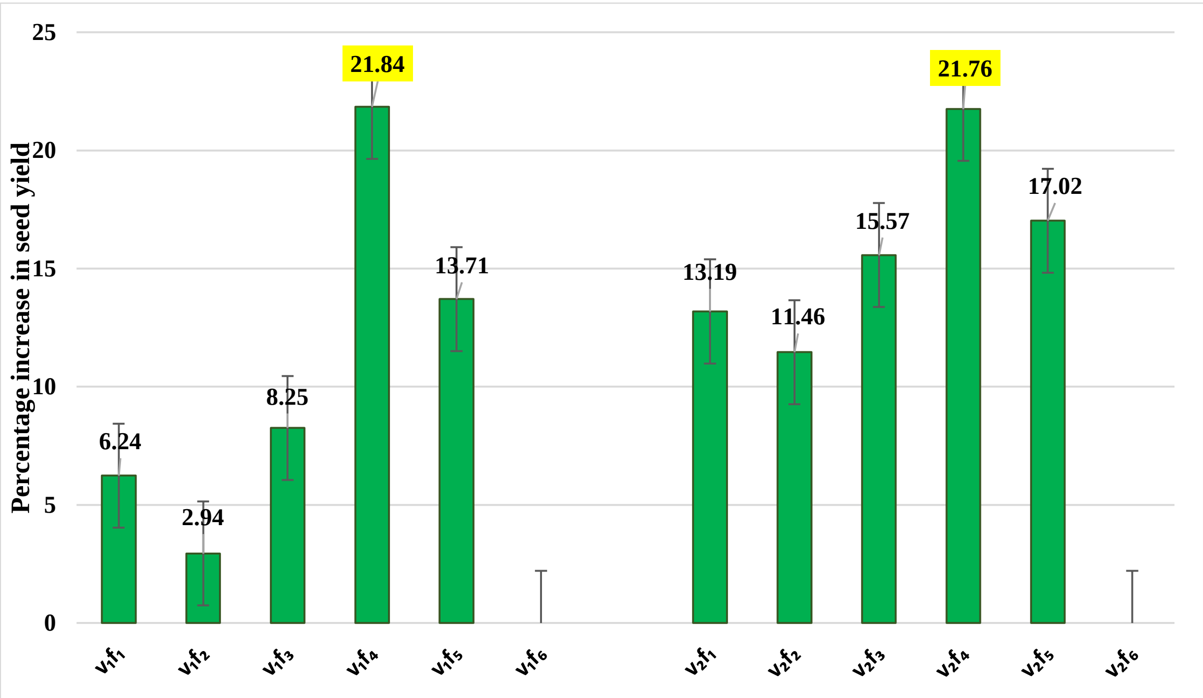

Fig. 22 Percentage increase in seed yield of Sumanjana and DBGV 5 against its corresponding control as influenced by foliar application

production. The results are in line with the observation made by Amanullah *et al.* (2008) who reported that increase in LAI increased the light interception and total dry matter production at various growth stages.

Among the growth regulators, NAA (20 mg L^{-1}) maintained higher dry weight of reproductive parts due to better source-sink relationship. The enhanced dry weight of reproductive parts by growth regulators might be due to increased translocation of assimilates from leaf and stem to reproductive parts. Similar results were also reported in soybean with the application of NAA (Shukla *et al.*, 1997). Improvement in dry weight of reproductive parts due to growth regulators application was also reported by Dashora and Jain (1994).

The pronounced effect of foliar application of water-soluble fertilizers on dry matter production had been reported by Pradeep and Elamathi (2007) and Sathyamoorthi *et al.* (2008b). The higher source activity leading to increased production and better translocation to the enhanced sink capacity was assured with foliar application of nutrients and PGRs. This may lead to increased growth attributes and enhanced chlorophyll formation resulting in higher photosynthetic rates contributing to better seed yield. Dixit and Elamathi (2007), Manonmani and Srimathi (2009), Rahman *et al.* (2014) and Janki *et al.* (2018) also reported similar findings.

Harvest index is a measure of physiological productivity potential of a crop variety and is interpreted as the ability to convert the dry matter into economic yield. It is computed as the ratio of economic yield to biological yield and varieties that have more seed yield and less biological yield would have higher harvest index values (Abdalla *et al.*, 2015). Higher the harvest index more will be the production efficiency and *vice versa.* Perusal of the data revealed that the varieties, foliar sprays and their combinations had no significant influence on harvest index during both seasons. The harvest index ranged from 0.29 to 0.34 and 0.28 to 0.33 during the summer and *Rabi* respectively while under open situation it ranged from 0.27 to 0.38 as reported by Yamini (2019).

5.2.5 Quality Attributes

The quality attributes *viz.*, grain dry matter and nitrate content were not influenced by varieties, foliar sprays and their interaction during both the seasons. However, grain protein was influenced by foliar sprays and the treatment foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded higher grain protein content and was on par with all other treatments except f_2 and f_6. Foliar spray of primary nutrients alone or in combination with plant growth regulators such as NAA / salicylic acid might have increased the N fixation in plants thereby contributing better conversion of nitrogen to protein. The improvement in protein content might be attributed to higher uptake of nitrogen during growth period which increased photosynthesis, synthesis of protoplasm and protein. Singhal *et al*. (2016) also reported significantly higher protein content in vegetable cowpea seeds compared to control with foliar nutrition of water-soluble NPK fertilizer (19:19:19) at 30, 45 and 60 DAT. The higher protein content was found with application of macro elements with hormones, could improve the photosynthetic activity and enzymes for carbohydrate transformation (Doss *et al.*, 2013).

5.2.6 Uptake of Nutrients

Nutrient uptake by crop is related to nutrient content in the plant and dry matter production; which in turn depends on the photosynthetic ability of the plant. During both the seasons, comparatively higher NPK uptake was observed in the varieties Sumanjana and DBGV 5. This might be attributed to higher content of N P K and increased growth attributes *viz.*, plant height, number of branches, number of leaves and LAI which resulted in higher dry matter production in the respective varieties.

Increased N, P and K contents in plant could be endorsed to the higher content in water soluble fertilizers which plant have absorbed directly through leaves. The results are found in agreement with the findings of Tohamy *et al.* (2011).

Regarding the subplot factor, foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded higher NPK uptake and was on par with f_3 and f_5 in summer season and the highest NPK uptake was recorded in f_4 during *Rabi*. Nutrients and PGRs applied *via* foliage helped in better absorption of nutrients and efficient translocation of photo assimilates to all parts of the plant leading to better activity of functional root nodules resulting in more leaf area, dry matter production and uptake of nutrients. This could have led to more flower production and subsequently pod formation and other yield attributing characters. Frizts (1978) pointed out that application of small units of foliar fertilizers at critical stages of plant growth stimulated plant metabolism and increased nutrient uptake.

During *Rabi*, Sumanjana along with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_4) recorded the highest NPK uptake due to the higher yield and dry matter accumulation. Tabassum *et al.* (2013) observed that increased availability of nutrients also accelerated the physiological processes which in turn influenced the dry matter production and nutrient uptake. N and K uptake were significantly higher and might have contributed to the increased yield. The results are in accordance with the reports of Sangwan and Raj (2004) in chickpea and Anitha *et al.* (2005) in cowpea. Increased photosynthetic efficiency, assimilation and dry matter production resulting from the better availability and uptake of nutrients was reported by Amjad *et al.* (2004) and Calhor (2006).

5.2.7 Soil Analysis after the Experiment

The varieties, foliar spray and their interaction did not exert any significant influence on soil pH and electrical conductivity during both the seasons. Nevertheless, increase in the soil pH status from initial value (5.9) was recorded with the cultivation of different blackgram varieties with foliar spray during both the seasons. This could be attributed to the effect of liming done before sowing. Liming can raise the soil pH (Goulding, 2016) as a result of desorption of the Al^{3+} and H^+ ions from the exchange sites to soil solution.

There was no significant variation in organic carbon solely due to varieties and foliar spray and their interaction in the summer season. During the *Rabi* season, the plots grown with the varieties, Sumanjana and DBGV 5 showed higher organic carbon contents. Wani *et al.* (2003) and Jensen *et al.* (2012) also reported that inclusion of legumes in rotation significantly improved the soil organic carbon and available nutrients in the soil. There was significant variation in organic carbon due to foliar spray in *Rabi* and the treatment 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded highest organic carbon. The enhancement in organic carbon content observed in all the treatments might be due to the decomposition of farmyard manure (20 t ha^{-1}) coupled with the left over residues of the previous crop after summer. Lynch and Whips (1990) revealed that about 40 per cent of dry matter accumulated by the plant was released into the rhizosphere as root exudates. Organic substances (organic acid, amino acid, sugars, vitamins, mucilage etc) released into the rhizosphere during the crop growth as well as due to the addition of organic matter in the form of FYM might have enhanced the organic carbon content of soil (Hasanuzzaman *et al.*, 2019). Bochalya *et al.* (2021) reported improved organic carbon status due to the foliar spray of 19:19:19 at flowering stage in wheat. The treatment combinations v_1f_4, v_2f_4 and v_5f_4 recorded higher organic carbon content and was on par with v_2f_5. Organic carbon was observed to have increased from the initial status (0.93) after the harvest of blackgram. There was significant improvement in the organic carbon status in the *Rabi* compared to the summer season. The probable reason of higher organic carbon in the *Rabi* might be due to the residue decomposition of summer crop in the next *Kharif* season and also due to the addition of organic manures to the *Rabi* crop.

Regarding the post experimental soil NPK status, significant difference was observed in case of N due to varieties, foliar sprays and their interaction. Variation in available P was significant with respect to foliar sprays only during *Rabi* season. However, there was an improvement in the N, P and K status compared to the initial status. Thamburaj (1991) revealed that legumes in rotation increased the NPK content of soil. The better crop establishment and rooting allowed the crop to tap nutrients from the deeper layers. Availability of N was found to be higher in treatments with higher organic carbon content which might be due to atmospheric N fixation by the symbiotic N fixing bacteria present in the nodule. The result is in accordance with the findings of Sakin (2012) who reported that high soil organic carbon enhanced the N content of the soil. Available P status in the soil after the experiment was found to be high in all the treatments. Higher soil organic carbon content prevented the leaching of nutrients and sustained the soil fertility status. Similar observation was also made by Suman (2018). The varieties Sumanjana and DBGV 5 recorded higher available N compared to other varieties which might be due to comparatively higher root nodulation, which is expected to have contributed more N in soil. In the case of subplot factor, foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) recorded higher N during both the seasons and the highest P status in *Rabi* season. This can be correlated with the higher nodules number and dry weight of nodules per plant observed in f_4 which might have contributed more biological N fixation and rhizo-deposition. This will mobilize the fixed P in the soil and make it in the available form. The interaction effect was a reflection of main and subplot effects and the treatment combination v_1f_4 and v_2f_4

recorded comparatively higher N status after the experiment during both the seasons. Even though, the uptake of N was higher in Sumanjana and DBGV 5, the greater contribution of N by fixation recorded increment in soil available N status. Exploration of the effect of legumes on soil enrichment have shown that nitrogen fixation and rhizodeposition of N from legumes increased the available N status in soil (Fustec *et al.,* 2010; Laberge *et al.,* 2011; Zhang *et al.,* 2015).

5.2.8 Economic Analysis

Adoption of any management strategy depends on the economic feasibility. The economic analysis for the different combinations reveled that the varieties Sumanjana (v_1) or DBGV 5 (v_2) supplied with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) found to be profitable recording higher gross returns, net returns and benefit cost ratio (BCR) during both the seasons. The higher economic benefits could be attributed to the higher seed yields realized, the treatments being the cumulative effects of the varieties and application of foliar nutrients and plant growth regulators. Mean values of net return (₹ 70411 ha^{-1}) and B: C ratio (2.04) were also the highest for the treatment v_1f_4, followed by the v_2f_4 (Fig. 23 and Fig. 25). The treatment combinations v_1f_4 and v_2f_4 realized an additional mean net income of ₹21378 and ₹16050 respectively compared to its respective control. There was 30.36 percent and 26.09 percent increase in net income (Fig. 24) in v_1f_4 and v_2f_4 compared to control (v_1f_6 and v_2f_6 respectively). Mamathasree (2014) and Kumar *et al.* (2018) obtained higher net returns and BCR in red gram and blackgram respectively due to foliar application of water-soluble fertilizer 19:19:19 at 2 per cent at flowering and pod development stages. Yalagar *et al.* (2021) also found that, application of recommended nutrients to pigeonpea coupled with foliar spray of 19:19:19 (1%) at flower initiation and peak flowering stage is optimum for higher net returns (₹ 65908 ha^{-1}) and BCR (3.49). Shwetha *et al.* (2021) registered

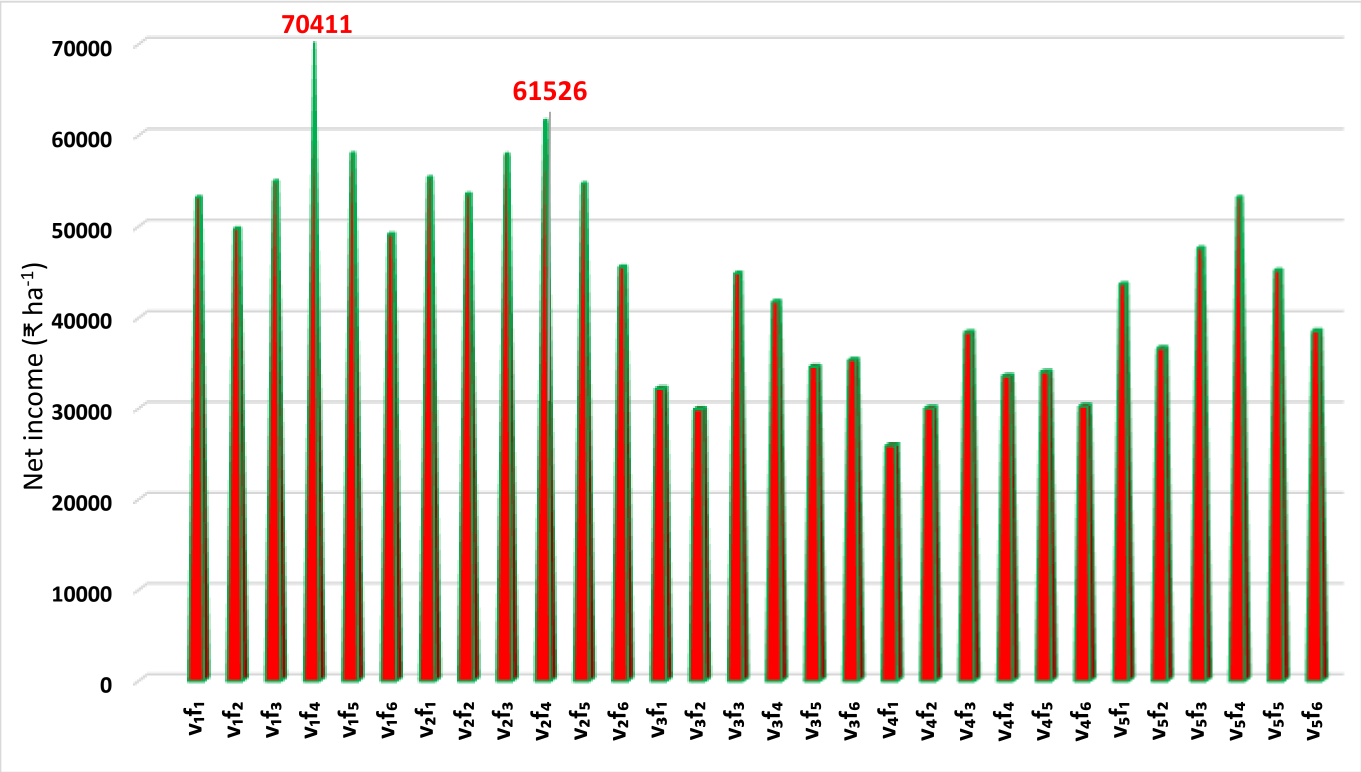

Fig. 23 Variation in mean net income as influenced by variation and foliar application

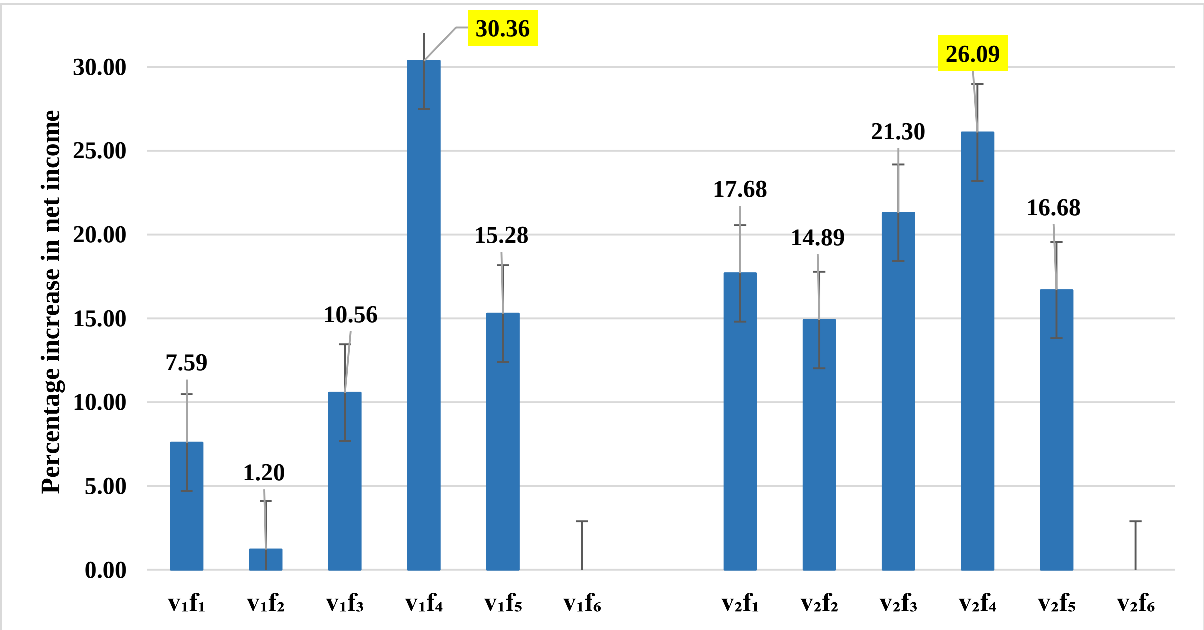

Fig. 24 Percentage increase in net income of Sumanjana and DBGV 5 against its corresponding control as influenced by foliar application

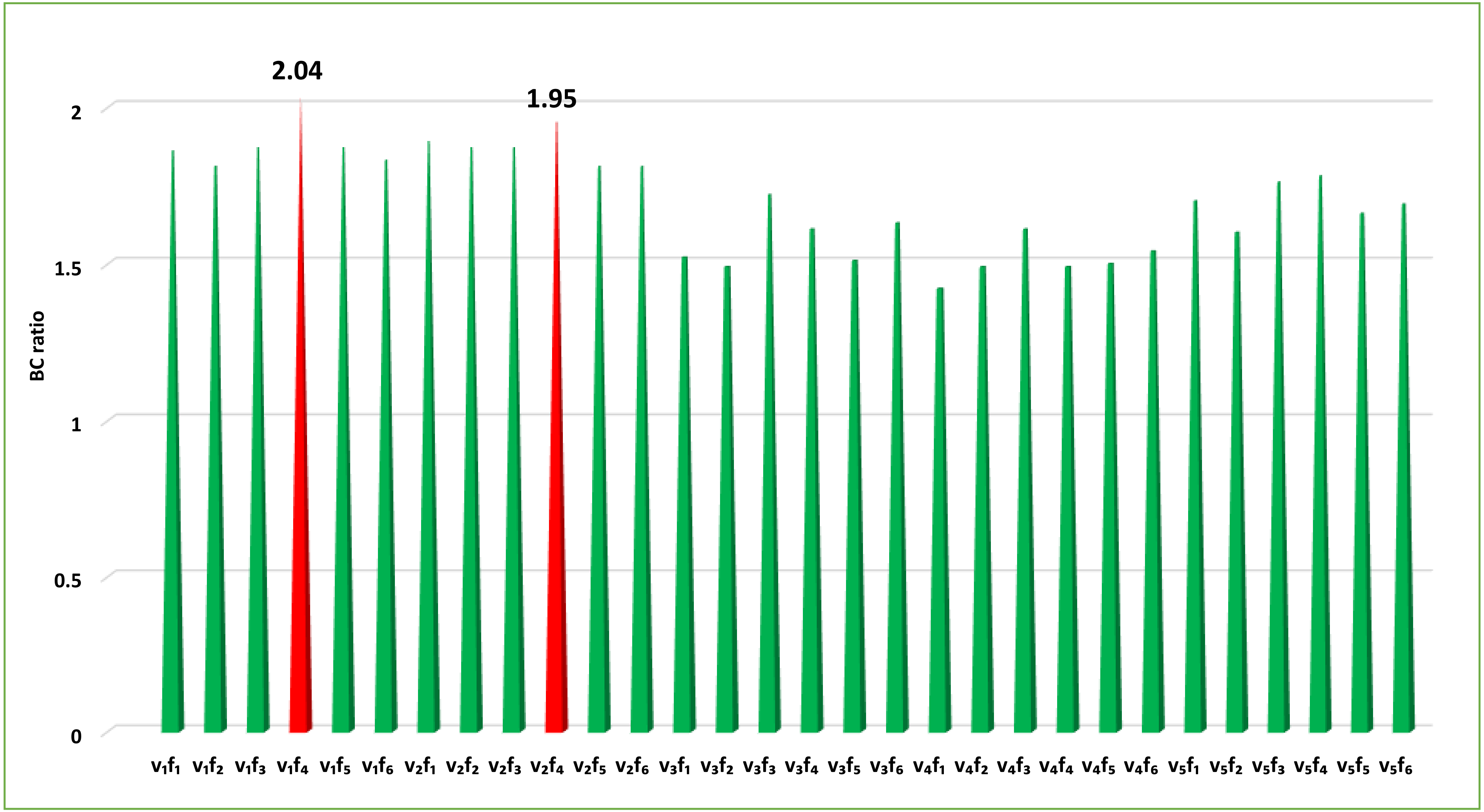

Fig. 25 Variation in mean B:C ratio as influenced by varieties and foliar application

higher net return (₹ 161,159 ha^{-1}) and B:C ratio (4.19) in pigeon pea due to the foliar application of Pulse magic (1%) + 19:19:19 (1%) + 50 ppm NAA + Borax (0.2%).

Based on the above findings, it could be inferred that the yield of blackgram is strongly influenced by the application of different nutrients and growth regulators indicating its importance of these compounds in increasing the yield potential through improving morpho-physiological and biochemical traits under partial shade. The seed yield in blackgram ultimately depends on the accumulation of photo assimilates and partitioning to different plant parts. The present study revealed that, the varieties DBGV 5 and Sumanjana, could perform better under partially shaded coconut garden. Higher yield could be realized in these varieties under partial shade with recommended dose of KAU POP supplemented with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering (35 DAS) and 15 days later. Sumanjana and DBGV 5 with f_4 recorded higher mean net income (₹ 70411 ha^{-1} and ₹ 61256 ha^{-1}) and mean B:C ratio (2.04 and 1.95).

SUMMARY

6. SUMMARY

The investigation entitled 'Productivity enhancement of blackgram (*Vigna mungo* (L.) Hepper) intercropped in coconut gardens' was undertaken at the College of Agriculture, Vellayani, Thiruvananthapuram during 2019 - 2021.

The research was aimed to identify shade tolerant blackgram varieties suitable for coconut gardens, to study the effect of foliar nutrition and plant growth regulators on growth and yield of the shade tolerant blackgram varieties intercropped in coconut garden and to work out the economics of cultivation. Coconut palms of above 40 years of age having a light intensity 56.25 klux, planted at spacing of 7.6 m x 7.6 m was selected at the Instructional Farm, College of Agriculture, Vellayani. The study was conducted as two separate experiments and the salient findings of the experiment are summarized in this chapter.

6.1 EXPERIMENT I: SCREENING OF BLACKGRAM VARIETIES FOR SHADE TOLERANCE (MICRO PLOT STUDY)

The first experiment on 'Screening of blackgram varieties for shade tolerance (micro plot study)' was conducted during *Rabi* 2019-20 in the selected coconut garden. Seeds of promising blackgram varieties (12 nos) along with culture (3 nos) collected from different research stations of south India *viz.*, Sumanjana, DU 1, DBGV 5, VBN 5, VBN 6, VBN 8, Rashmi, CO 6, TAU 1, TAU 2, Blackgold, AKU 15, Culture 4.5.8 (T 9 x Rusami), Culture 4.5.18 (T 9 x Rusami) and Culture 4.6.1 (T 9 x Rusami) were raised in plots (1.0 m x 0.9 m) laid out in randomized block design replicated thrice. A distance of two meter radius was left from the base of palm to avoid root interference making a length of 3.6 m in between the palms for sowing. Land was ploughed and crop was sown at a spacing of 25 cm x 15 cm in the raised beds. The recommended nutrients (20:30:30 kg N: P_2O_5: K_2O ha^{-1}) were given through urea, rajphos and muriate of potash (KAU, 2016). Half the dose of N, full P and K were given as basal and the remaining half dose of N was given as two foliar sprays at 15 and 30 days after sowing (DAS). Two weedings were done at 15 and 30 DAS with irrigation provided on alternate days.

The summary of results of the experiment I is as follows.

Among the varieties, DBGV 5, CO 6 and Sumanjana were found to grow taller right from one month after sowing (MAS) till harvest under low light while culture 4.5.18, culture 4.5.8 and VBN 5 maintained a shorter stature. Number of leaves per plant also varied among varieties under low light intensity at 1 MAS and at harvest. The varieties that have grown taller namely DBGV 5, CO 6, Sumanjana, VBN 5 and VBN 6 produced more number of leaves at 1 MAS. At 2 MAS, significant difference in terms of number of leaves per plant was not evident among the varieties/cultures. The number of branches per plant varied significantly at 1 MAS only and in the later stage, there was no significant influence among the varieties and cultures.

The results revealed remarkable influence of shading stress on leaf area index (LAI) at flowering of blackgram varieties and cultures tested. Taller plants with more number of leaves at 50 per cent flowering resulted in a notable increase in LAI in both CO 6 and DBGV 5 recording 5.77 and 5.36 and least in TAU 1 with a LAI of 3.36. The variety CO 6 recorded higher leaf area duration (65.66 days) and was comparable with DBGV 5 (58.40 days). No significant difference was observed in number and dry weight of nodules per plant at flowering among the varieties and cultures considered under this study.

Physiological and biochemical characters of varieties and cultures varied significantly in response to low light intensity at flowering. Photosynthetic rate was the highest for DBGV 5 and VBN 5 followed by CO 6. The leaf persistence measured *via* leaf area duration was higher for the varieties CO 6 and DBGV 5 and all the cultures had recorded lower persistence of leaf. The varieties DBGV 5, TAU 2, Sumanjana and VBN 8 recorded higher stomatal index. Chlorophyll a and total chlorophyll content were higher for DBGV 5 and was on par with Sumanjana. Higher value of chlorophyll b was recorded by the varieties VBN 8, VBN 5, TAU 1 and culture 4.5.18.

The varieties DBGV 5 and Sumanjana were early to flower compared to other varieties and cultures whereas TAU 2 took the maximum number of days to reach 50 per cent flowering and was on par with VBN 5, VBN 6, DU 1 and Rashmi. The variety DBGV 5 resulted in higher number pods per plant which was on par with CO 6, VBN 5, VBN 6, Sumanjana and Rashmi.

Varietal difference did not show a remarkable influence on length of pod and number of seeds per pod. However, 100 seed weight was an important yield determining character of each variety and culture and varied significantly. The culture 4.6.1 produced bold seeds with the highest 100 seed weight (5.06) and was on par with DBGV 5, DU 1, Blackgold, TAU 1 and AKU 15. The variety DBGV 5 produced the highest seed yield per plant followed by VBN 5 and Sumanjana. Haulm yield per plant was higher for DBGV 5 and was on par with VBN 5, Sumanjana and CO 6. The highest seed yield was recorded by DBGV 5 with 1183 kg ha^{-1}; followed by VBN 5 (917 kg ha^{-1}) and Sumanjana (907 kg ha^{-1}) under shading stress. Varieties and cultures varied significantly with respect to haulm yield also. The highest haulm yield was recorded in the varieties DBGV 5 followed by VBN 8. Similar to seed yield, different varieties and cultures showed variability in dry matter partitioning and harvest index. The varieties DBGV 5, VBN 5 and Sumanjana were having more assimilates in the reproductive part than the vegetative part. The shoot dry weight and leaf dry weight were the highest in culture 4.5.8 and consequently it produced the lowest seed yield among all the varieties and cultures. The added effect of vegetative and reproductive parts resulted in variation in total dry matter production with higher value registered by the varieties AKU 15, VBN 8, VBN 5 and DBGV 5. Higher harvest index was recorded by Sumanjana which was on par with DBGV 5 and VBN 6.

6.2 EXPERIMENT II: PERFORMANCE EVALUATION OF SHADE TOLERANT VARIETIES UNDER FOLIAR APPLICATION OF NUTRIENTS AND GROWTH REGULATORS IN RAINFED COCONUT GARDEN

The second experiment on 'Performance evaluation of shade tolerant varieties under foliar application of nutrients and growth regulators in rainfed coconut garden' was conducted during summer 2020 and the confirmation trial during *Rabi* 2020-21. The field was laid out in split plot design with varieties (5) as main plot treatments foliar spray as subplot treatments (6). Five varieties which performed better under the partial shade in coconut garden were selected based on growth, yield attributing characters and yield (v_1 - Sumanjana, v_2 - DBGV 5, v_3 - VBN 5, v_4 - VBN 6 and v_5 - CO 6). The subplot treatments were six different foliar spray of nutrients and plant growth regulators (f_1: Foliar spray of 19:19:19 @ 1% at 45 and 60 DAS, f_2: Foliar spray of SOP @ 0.5% at 45 and 60 DAS, f_3: NAA 40 mg L^{-1} and salicylic acid 100 mg L^{-1} at pre-flowering (30-45 DAS) and 15 days later, f_4: f_3 + $f_{1,}$ f_5: f_3 + f_2 and f_6: Control - KAU POP). Main plots of 6 m x 3 m were laid out in between the coconuts and divided it into subplots of 3 m x 1 m size with four replications. The five varieties were planted in the main plots at 25 cm x 15 cm spacing. Farmyard manure @ 20 t ha^{-1} was given as basal and NPK @ 20: 30: 30 kg ha^{-1} was given uniformly in all the plots as per KAU POP. Half N + full P + full K (basal) as soil application and the remaining half N as foliar spray of urea at 15 and 30 DAS (KAU, 2016). The foliar sprays of nutrients and PGRs were given as per the treatments, and the growth, physiological and yield attributes were recorded. The salient findings of the experiment II for two seasons is as follows.

Growth attributes varied significantly due to varieties, foliar spray and their interaction at all the stages during both the seasons. At 1 MAS, among the varieties, Sumanjana (v_1) produced the tallest plants in summer and Sumanjana (v_1) and CO 6 (v_5) were taller and were comparable during *Rabi*. At 2 MAS, VBN 6 (v_4) recorded the tallest plants in summer and Sumanjana (v_1) produced taller plants and was on par with DBGV 5 (v_2) during *Rabi*. At the time of harvest, Sumanjana (v_1) and CO 6 (v_5) were taller during summer and Sumanjana had the tallest plants during *Rabi*. The varieties significantly influenced the number branches per plant at all the growth stages during summer and Sumanjana (v_1) and CO 6 (v_5) recorded higher number of branches at 1 MAS and 2 MAS. Sumanjana produced higher number of branches with more number of leaves during both the seasons. At flowering, higher LAI, number and dry weight of nodules per plant were realized by Sumanjana and was on par with CO 6 (v_5) in summer and DBGV 5 (v_2) in *Rabi*.

The subplot factor foliar spray had significant effect on growth attributes of blackgram varieties at all the stages during both the seasons. Foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in significantly taller plants, more number of branches and leaves. At flowering, the highest LAI, number and dry weight of nodules per plant were recorded in f_4 during both the seasons. The highest root dry weight (0.64 g) was recorded in f_4 during *Rabi* season.

Among the treatment combinations, Sumanjana (v_1) with f_4 produced taller plants at 2 MAS, higher number of branches and leaves per plant during summer and *Rabi*. At harvest, there was significant influence on number of branches per plant due to interaction at summer season and the treatment combinations v_1f_4, v_2f_4, v_5f_4, v_1f_5 and v_2f_3 recorded higher values of number of branches per plant and were comparable. The treatment combination v_1f_4 recorded higher number of leaves per plant at harvest during summer and was on par with v_1f_5 and the highest number of leaves per plant was registered by v_1f_4 during second season. Leaf area index was recorded higher for the treatment v_1f_4 followed by v_2f_4 during both the seasons. The treatment combination v_1f_4 produced higher number of nodules per plant at flowering and was on par with v_2f_4 and v_5f_4 in the first season and the treatment combination v_1f_4 and v_5f_4 were on par during *Rabi* season.

Sumanjana exhibited the highest crop growth rate (CGR) and relative growth rate (RGR) during both the seasons at 45-60 DAS. VBN 6 evinced the highest RGR between 30-45 DAS; and Sumanjana between 45-60 DAS during both the seasons. However, DBGV 5 recorded the highest net assimilation rate (NAR) between 30-45 DAS and 45-60 DAS during both the seasons. The varieties, DBGV 5, VBN 5 and VBN 6 had higher NAR between 60 - 75 DAS in summer seasons. Specific leaf weight was the highest in VBN 5 at 30 DAS, and Sumanjana at 45, 60 and 75 DAS. The highest chlorophyll content was recorded by DBGV 5 during summer and by Sumanjana during *Rabi.* The highest stomatal conductance and lower stomatal index were recorded in Sumanjana during both the seasons.

Between 30-45 DAS and 45-60 DAS, higher CGR was recorded in f_4 during both the seasons and f_3 had the highest CGR between 60 DAS- harvest during both the seasons. Between 45-60 DAS, f_4 recorded the highest RGR in both the seasons; f_3 recorded the highest RGR between 60-75 DAS during summer and f_2 during *Rabi* season. The subplot factor f_4 recorded higher value of SLW at 30 DAS, 45 DAS, and at 75 DAS during both the seasons. Specific leaf weight was significantly higher in f_3 in summer and f_3 and f_5 were higher and on par with each other during *Rabi* season at 60 DAS. During summer, f_3, f_4 and f_5 recorded higher NAR between 45-60 DAS. Higher value of chlorophyll content, SLW and the highest stomatal conductance were recorded in f_4 during both the seasons.

Sumanjana (v_1) in combination with f_4 measured significantly higher CGR and RGR (at active growth stages), highest chlorophyll content, stomatal conductance and lower stomatal index during both the seasons. The interaction effect of varieties and foliar sprays have significant effect on SLW at 45 DAS, 60

DAS and at harvest and the treatment combination v_1f_4 recorded the highest value of SLW in both the seasons.

Sumanjana (v_1) flowered earlier compared to other varieties during both the seasons and produced the highest number of pods per plant. Hundred seed weight was higher for DBGV 5 and was on par with Sumanjana during both the seasons. Seed yield per plant recorded was higher for Sumanjana and comparable with DBGV 5. DBGV 5 and Sumanjana produced higher haulm yield during both the seasons. Higher TDMP was registered for Sumanjana and was on par with DBGV 5 during summer and *Rabi*.

The P content was higher in Sumanjana during summer and *Rabi* season and was on par with CO 6. Sumanjana recorded higher NPK uptake in both the seasons followed by DBGV 5. Available N was the highest with v_1 during summer season and v_1 and v_2 during *Rabi*.

Plants supplied with foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_3) attained 50 per cent flowering earlier and was on par with f_5. The highest number of pods per plant, 100 seed weight, seed yield, haulm yield and TDMP were produced by f_4 during both the seasons. The grain protein (%) content was improved by 19:19:19 (1%) at 45 and 60 DAS + NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) and was on par with f_3, f_1 and f_5. Plants applied with f_4 recorded higher NPK uptake and was on par with f_3 and f_5 during summer. The highest NPK uptake and organic carbon was recorded in f_4 during *Rabi*. Available N and P were the highest in f_4 during both the seasons.

The variety Sumanjana supplied with NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (v_1f_3) flowered earlier during both the seasons. The number of pods per plant recorded were significantly higher in v_1f_4 and 100 seed weight during both the seasons. A higher seed yield was realized in v_1f_4 which was on par with v_2f_4 during summer. Seed yield was the highest in v_1f_4 during *Rabi*. Haulm yield and TDMP recorded were higher for v_1f_4 and was on par with v_2f_4 during both the seasons. The treatment combination v_1f_4 recorded the highest N uptake in *Rabi* season.

The available N status in soil was higher during both the seasons in v_1f_4 with the highest NPK uptake during *Rabi*. Higher net income and BCR were registered in v_1f_4 followed by v_2f_4 during both the seasons. Sumanjana with f_4 realized the highest mean net income of ₹ 70411 ha^{-1} and BCR of 2.04 followed by DBGV 5 with f_4.

The present study identified DBGV 5 and Sumanjana as shade tolerant blackgram varieties with superior growth and yield attributes under partial shade and could be recommended for intercropping in coconut garden. Further, the yield of the shade tolerant varieties could be enhanced by recommended dose of nutrients as per KAU package supplemented with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering (35 DAS) and 15 days later. Sumanjana and DBGV 5 raised under partial shade in coconut garden with recommended dose of nutrients as per KAU package supplemented with the above said foliar spray realized higher mean net income (₹ 70,411 ha^{-1} and ₹ 61,256 ha^{-1}) and mean B:C ratio (2.04 and 1.95).

FUTURE LINE OF WORK

- The suitability of other short duration pulses to partial shade in coconut garden
- The compatibility of water-soluble fertilizers with PGRs for foliar application
- The residual effect of long-term intercropping of shade tolerant blackgram on yield of coconut
- Carbon sequestration potential of coconut garden on long term intercropping with shade adaptive pulse crops

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APPENDICES

APPENDIX I

Weather data during the cropping period (*Rabi* 2019-20)

Standard week	Date	Temperature(℃)		Relative humidity (%)	Rainfall (mm)
		Maximum temperature	Minimum temperature		
40	Oct 2 to 7	31.50	24.70	81.61	3.70
41	Oct 8 to 14	31.10	24.40	84.36	2.70
42	Oct 15 to 21	30.90	24.20	87.57	2.00
43	Oct 22 to 28	30.90	23.60	84.50	1.40
44	Oct 29 to Nov 4	30.90	24.00	86.86	1.70
45	Nov 5 to 11	30.30	24.80	78.71	3.50
46	Nov 12 to 18	28.80	24.60	79.07	3.60
47	Nov 19 to 25	32.10	24.30	83.43	3.40
48	Nov 26 to Dec 2	32.60	24.50	81.57	3.10
49	Dec 2 to 9	32.00	24.10	80.43	2.90
50	Dec 9 to 16	32.20	23.60	80.93	3.30
51	Dec 17 to 23	31.40	23.90	82.64	2.40
1	Jan 1 to 7	31.90	23.76	80.88	2.75
2	Jan 8 to 10	32.23	24.10	79.86	3.10

APPENDIX II

Weather data during the cropping period (Summer 2020)

Standard week	Date	Temperature(°C)		Relative humidity (%)	Rrainfall (mm)
		Maximum temperature	Minimum temperature		
7	Feb 15 to Feb 18	32.98	23.55	74.88	0
8	Feb 19 to Feb 25	33.10	23.20	74.64	0
9	Feb 26 to Mar 4	33.20	23.40	75.25	37.60
10	Mar 5 to Mar 11	33.20	24.30	76.71	3.00
11	Mar 12 to Mar 18	33.40	24.60	73.29	0
12	Mar 19 to Mar 25	33.70	25.00	74.21	11.70
13	Mar 26 to April 1	34.10	25.10	72.21	0
14	April 2 to April 8	34.10	25.00	72.29	19.60
15	April 9 to April 15	33.90	25.60	73.86	2.90
16	April 16 to April 22	34.60	25.90	72.83	4.80
17	April 23 to April 29	34.40	25.94	75.43	60.30
18	April 30 to May 6	34.20	26.20	73.57	43.00
19	May 7 to May 13	32.60	25.70	84.79	105.70
20	May 14 to May 20	31.50	24.90	85.86	125.70
21	May 21 to May 25	31.88	25.60	87.70	123.40

APPENDIX III

Weather data during the cropping period (*Rabi* 2020-21)

Standard week	Date	Temperature (℃)		Relative humidity (%)	Rainfall (mm)
		Maximum temperature	Minimum temperature		
43	Oct 24 to Oct 28	31.9	25.3	86.5	0.4
44	Oct 29 to Nov 4	32.4	25.2	81.6	0
45	Nov 5 to Nov 11	33.2	25.8	84.2	2.4
46	Nov 12 to Nov 18	30.6	24.5	90.4	71.0
47	Nov 19 to Nov 25	32.6	24.9	83.5	0
48	Nov 26 to Dec 2	33.0	25.1	83.4	11.7
49	Dec 3 to Dec 9	31.3	24.3	87.5	60.9
50	Dec 10 to Dec 16	32.8	24.4	84.1	4.0
51	Dec 17 to Dec 23	32.2	23.9	88.9	9.5
52	Dec 24 to Dec 31	33.2	23.6	82.1	0
1	Jan 1 to Jan 7	32.0	23.6	89.4	32.2
2	Jan 8 to Jan 14	30.4	24.0	91.1	45.0

APPENDIX IV

Average cost of inputs and price of the produce

Items	Costs (₹)
Inputs	
Blackgram seeds	180 kg^{-1}
Lime	15 kg^{-1}
Dried cow dung powder	5 kg^{-1}
Urea	10 kg^{-1}
Rajphos	15 kg^{-1}
Muriate of potash	17 kg^{-1}
Sulphate of potash	70 kg^{-1}
19:19:19 NPK	130 kg^{-1}
Naphthalene acetic acid	1682 for 25 g
Salicylic acid	730 for 500 g
Insecticide (CORAGEN®)	210 for 10 mL
Labour cost	829 per person
Produce	
Price of unprocessed blackgram	80 kg^{-1}

PRODUCTIVITY ENHANCEMENT OF BLACKGRAM (*Vigna mungo* (L.) Hepper) INTERCROPPED IN COCONUT GARDENS

by

POOJA A. P.

(2018-21-009)

ABSTRACT

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ABSTRACT

The research work entitled 'Productivity enhancement of blackgram (*Vigna mungo* (L.) Hepper) intercropped in coconut gardens' was undertaken at College of Agriculture, Vellayani during 2018-2021. The study aimed to identify shade tolerant blackgram varieties suitable for coconut gardens, to study the effect of foliar nutrition and plant growth regulators on growth and yield of the shade tolerant blackgram varieties intercropped in coconut garden and to work out the economics of cultivation. The investigation was carried out as two experiments: (i) screening of blackgram varieties for shade tolerance, and (ii) performance evaluation of shade tolerant varieties under foliar application of nutrients and growth regulators in rainfed coconut garden.

The first experiment was conducted during *Rabi* 2019-20 in coconut garden having a light intensity equivalent to 50 per cent of that under open condition (56.25 klux), planted at a spacing of 7.6 m x 7.6 m. Seeds of 12 promising blackgram varieties collected from different research stations of south India (Sumanjana, DU 1, DBGV 5, VBN 5, VBN 6, VBN 8, Rashmi, CO 6, TAU 1, TAU 2, Blackgold and AKU 15) and three cultures (Culture 4.5.8, Culture 4.5.18 and Culture 4.6.1), were raised in micro plots laid out in randomized block design with three replications. The crop was raised as per KAU package of practices.

The results of the study revealed significant variation in growth characters among the varieties screened for shade tolerance under partial shade in coconut garden. Plants of DBGV 5 were significantly taller (96.89 cm) with higher initial number of leaves at all the stages and was on par with Sumanjana and CO 6. Higher leaf area index (LAI) and leaf area duration were recorded in CO 6 (5.77, 65.66 days) and DBGV 5 (5.36, 58.40 days) followed by Sumanjana.

Early flowering was observed in Sumanjana (34.33 days) and DBGV 5 (36.33 days). The variety DBGV 5 had the highest photosynthetic rate and resulted in significantly more pods per plant (23.67) which was on par with CO 6, VBN 5, VBN 6, Sumanjana and Rashmi. DBGV 5 produced the highest seed yield per plant

(5.44 g) followed by VBN 5 and Sumanjana. Haulm yield per plant was higher for DBGV 5 (19 g) and was on par with VBN 5, Sumanjana and CO 6. The variety DBGV 5 produced the highest seed yield (1183 kg ha^{-1}) followed by VBN 5, Sumanjana and CO 6. A higher harvest index of 0.24 was recorded by Sumanjana which was on par with DBGV 5 and VBN 6.

Among the varieties screened, five varieties which performed better in terms of yield per unit area under the partial shade in coconut garden *viz.*, DBGV 5, VBN 5, Sumanjana, CO 6 and VBN 6 were selected for experiment II undertaken in summer 2020 followed by the confirmatory trial during *Rabi* 2020 -21. The experiment was laid out in split plot design with five varieties (v_1 - Sumanjana, v_2 - DBGV 5,v_3 - VBN 5,v_4 - VBN 6,v_5 - CO 6) as main plot treatments and six foliar sprays of nutrients and plant growth regulators as subplot treatments (f_1: 19:19:19 (1%) at 45 and 60 DAS, f_2: SOP (0.5%) at 45 and 60 DAS, f_3: NAA 40 mg L^{-1} and salicylic acid 100 mg L^{-1} at pre-flowering (30-45 DAS) and 15 days later, f_4: $f_3 + f_1$, f_5: $f_3 + f_2$ and f_6: Control - KAU POP).

Among the varieties, Sumanjana (v_1) grew taller during both the seasons and was comparable with CO 6 and DBGV 5 at harvest. Sumanjana produced higher number of branches with more number of leaves during both the seasons. At flowering, higher LAI, number and dry weight of nodules per plant were realized by Sumanjana and was on par with CO 6 (v_5) in summer and DBGV 5 (v_2) in *Rabi.*

Sumanjana exhibited the highest crop growth rate (CGR) and relative growth rate (RGR) during both the seasons at 45-60 DAS. However, DBGV 5 recorded the highest net assimilation rate (NAR) between 30-45 DAS and 45-60 DAS during both the seasons. The highest chlorophyll content was recorded by DBGV 5 (1.96 mg g^{-1} fresh tissue) during summer and by Sumanjana (2.36 mg g^{-1} fresh tissue) during *Rabi.* The highest stomatal conductance (30.22 m moles m^{-2} s^{-1} and 28.34 m moles m^{-2} s^{-1}) and lower stomatal index (15.16% and 13.34%) were recorded in Sumanjana during both the seasons.

The variety Sumanjana flowered earlier compared to other varieties during both the seasons and produced the highest number of pods per plant (27.30 and 26.54). Hundred seed weight was significantly higher for DBGV 5 (5.01 g and 4.92 g) and remained at par with Sumanjana (4.99 g and 4.88 g) during both the seasons. Seed yield, haulm yield and total dry matter production (TDMP) were higher for Sumanjana and comparable with DBGV 5 during both the seasons. Sumanjana recorded higher NPK uptake during both the seasons followed by DBGV 5.

The subplot factor foliar spray had significant effect on growth, physiological and yield attributes of blackgram varieties. Foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering and 15 days later (f_4) resulted in significantly taller plants, more number of branches and leaves. The highest CGR, RGR (at 45-60 DAS), LAI, number and dry weight of nodules per plant at flowering were recorded in f_4 during both the seasons. During summer, f_3, f_4 and f_5 recorded higher NAR between 45-60 DAS. Higher chlorophyll content and stomatal conductance were recorded by f_4 during both the seasons. Plants supplied with f_3 attained 50 per cent flowering earlier and was on par with f_5 during both the seasons. Highest number of pods per plant, 100 seed weight, seed yield, haulm yield and TDMP were recorded by f_4 during both seasons. The grain protein content was improved by f_4 and was on par with f_3, f_1 and f_5. The NPK uptake was higher in f_4 and was on par with f_3 and f_5 during summer. Significantly higher organic carbon, available N and P was recorded in f_4.

Among the treatment combinations, Sumanjana (v_1) with f_4 produced taller plants at two months after sowing (MAS), higher number of branches and leaves per plant during summer and *Rabi*. Leaf area index, number of nodules and dry weight of nodules at flowering were higher for v_1f_4 followed by v_2f_4. Sumanjana in combination with f_4 measured significantly higher CGR and RGR (at active growth stages), highest chlorophyll content, stomatal conductance and lower stomatal index during both the seasons.

The variety Sumanjana with f_4 produced superior number of pods per plant (30.24 and 29.40) and hundred seed weight during summer and *Rabi*. A higher seed yield was realized in v_1f_4 (1750 kg ha^{-1}) which was on par with v_2f_4 (1713 kg ha^{-1}) during summer. Seed yield was the highest (1700 kg ha^{-1}) in v_1f_4 during *Rabi*. Haulm yield and TDMP recorded were higher for v_1f_4 and was on par with v_2f_4 during both the seasons. The available N status in soil was higher during both the seasons in v_1f_4 with the highest NPK uptake during *Rabi*. Sumanjana and DBGV 5 with f_4 realized higher mean net income (₹ 70411 ha^{-1} and ₹ 61256 ha^{-1}) and mean B: C ratio (2.04 and 1.95).

The present study identified DBGV 5 and Sumanjana as shade tolerant blackgram varieties with superior growth and yield attributes under partial shade and could be recommended for intercropping in coconut garden. Further, the yield of the shade tolerant varieties could be enhanced by recommended dose of nutrients as per KAU package supplemented with foliar spray of 19:19:19 (1%) at 45 and 60 DAS + foliar spray of NAA 40 mg L^{-1} and SA 100 mg L^{-1} at pre-flowering (35 DAS) and 15 days later. Sumanjana and DBGV 5 raised under partial shade in coconut garden with recommended dose of nutrients supplemented with the above said foliar spray realized higher mean net income and mean B: C ratio.

സംഗ്രഹം

'തെങ്ങിൻ തോപ്പുകളിലെ ഇടവിളകൃഷിയായി ഉഴുന്നിന്റെ ഉല്പാദനക്ഷമത വർദ്ധിപ്പിക്കൽ' എന്ന വിഷയത്തിൽ വെള്ളായണി കാർഷിക കോളേജിൽ 2018–21 കാലയളവിൽ ഒരു ഗവേഷണ പഠനം നടത്തുകയുണ്ടായി. തെങ്ങിൻ തോപ്പുകളിലെ തണലിൽ വളർത്താൻ അനുയോജ്യമായ ഉഴുന്നിനങ്ങൾ കണ്ടെത്തുക, ഈ ഉഴുന്നിനങ്ങളിൽ പോഷകങ്ങളും വളർച്ചാ ത്വരിതങ്ങളും പത്രപോഷണത്തിലൂടെ നൽകി ഉത്പാദനക്ഷമത വർദ്ധിപ്പിക്കുക, കൃഷിച്ചെലവ് കണക്കാക്കുക എന്നിവയായിരുന്നു പഠന ലക്ഷ്യങ്ങൾ. രണ്ടു വ്യത്യസ്ത പരീക്ഷണങ്ങളായി തുറസ്സായ സ്ഥലത്തു ലഭിക്കുന്ന പ്രകാശത്തിന്റെ 50 ശതമാനം ലഭിക്കുന്ന തെങ്ങിൻ തോപ്പിലാണ് പരീക്ഷണം നടത്തിയത്.

തണലിനെ പ്രതിരോധിക്കുന്ന ഉഴുന്നിനങ്ങളെ തിരഞ്ഞെടുക്കുന്നതിനുള്ള ആദ്യത്തെ പരീക്ഷണം 2019–20 റാബിയിലാണ് നടത്തിയത്. ദക്ഷിണേന്ത്യയിലെ വിവിധ ഗവേഷണ കേന്ദ്രങ്ങളിൽ നിന്നുള്ള പന്ത്രണ്ട് ഉഴുന്നിനങ്ങളും (സുമഞ്ജന, ഡി യു–1, ഡി ബി ജി വി–5, വി ബി എൻ–5, വി ബി എൻ–6, വി ബി എൻ–8, രശ്മി, സി ഓ–6, ടി എ യു–1, ടി എ യു–2, ബ്ലാക്ക്ഗോൾഡ്, എ കെ യു–15), മൂന്ന് കൾച്ചറും (കൾച്ചർ 4.5.8, കൾച്ചർ 4.5.18, കൾച്ചർ 4.6.1) റാൻഡമൈസെഡ് ബ്ലോക്ക് ഡിസൈനിൽ മൈക്രോ പ്ലോട്ടുകളിലായി മൂന്ന് റെപ്ലിക്കേഷൻ നിലനിർത്തിക്കൊണ്ട് കേരള കാർഷിക സർവകലാശാലയുടെ വിളപരിപാലന നിർദ്ദേശങ്ങൾ അനുസരിച്ച് പരിപാലിച്ചു.

ഒരു ഹെക്ടറിൽ നിന്നുള്ള വിളവ് കണക്കാക്കിയപ്പോൾ ഡി ബി ജി വി–5 ആണ് ഏറ്റവും മികച്ചതായി രേഖപ്പെടുത്തിയത്. ഇതിനു പിന്നിലായി വി ബി എൻ–5, സുമഞ്ജന, സി ഓ–6 തുടങ്ങിയ ഉഴുന്നിനങ്ങളും മികച്ച വിളവ് നൽകുന്നതായി നിരീക്ഷിച്ചു.

തെങ്ങിൻ തോപ്പിലെ ഭാഗികമായ തണലിൽ വിളവിന്റെ അടിസ്ഥാനത്തിൽ മികച്ചതായി കണ്ടെത്തിയ അഞ്ച് ഇനങ്ങൾ ആണ് ഡി ബി ജി വി–5, വി ബി എൻ–5, സുമഞ്ജന, സി ഓ–6, വി ബി എൻ–6. രണ്ടാമത്തെ പരീക്ഷണത്തിനായി സ്പ്ലിറ്റ് പ്ലോട്ട് ഡിസൈനിൽ ഈ അഞ്ച് ഇനങ്ങൾ മെയിൻ പ്ലോട്ട് ട്രീറ്റ്മെന്റുകൾ ആയും

പോഷകങ്ങളും വളർച്ചാ ത്വരിതങ്ങളും ആറു സബ് പ്ലോട്ട് ട്രീറ്റ്മെന്റുകൾ ആയും നാലു റെപ്ലിക്കേഷനും നൽകി. സബ് പ്ലോട്ട് ട്രീറ്റ്മെന്റുകൾ ഇപ്രകാരമായിരുന്നു, f_1: 19:19:19 ഒരു ശതമാനം വീര്യത്തിൽ, നട്ട് 45 ഉം 60 ഉം ദിവസത്തിന് ശേഷം , f_2: സൾഫേറ്റ് ഓഫ് പൊട്ടാഷ് 0.5 ശതമാനം വീര്യത്തിൽ, നട്ട് 45 ഉം 60 ഉം ദിവസത്തിന് ശേഷം, f_3: നാഫ്ത്തലീൻ അസറ്റിക് ആസിഡ് (എൻ എ എ) 40 മില്ലി ഗ്രാമും സാലിസിലിക് ആസിഡ് 100 മില്ലി ഗ്രാമും ഒരു ലിറ്ററിന് എന്ന തോതിൽ പൂവിടുന്നതിനു മുൻപും, തുടർന്ന് 15 ദിവസങ്ങൾ കഴിഞ്ഞും, f_4: $f_3 + f_1$, f_5: $f_3 + f_2$, f_6: കേരള കാർഷിക സർവകലാശാലയുടെ വിള പരിപാലന രീതി (കൺട്രോൾ).

സുമഞ്ജന എന്ന ഉഴുന്നിനം കുറഞ്ഞ ദിവസങ്ങൾക്കുള്ളിൽ തന്നെ പൂവിടുകയും ഒരു ചെടിയിൽ കൂടുതൽ കായ്കൾ തരുന്നതിലും വിളവിലും രണ്ടു വർഷങ്ങളിലും മികച്ചതായി കാണപ്പെട്ടു. ഒപ്പം ഡി ബി ജി വി-5 മികച്ച വളർച്ചയും ഉല്പാദനവും രേഖപ്പെടുത്തി.

ഒരു ചെടിയിൽ നിന്ന് ലഭിക്കുന്ന കായ്കളുടെ എണ്ണം, 100 വിത്തുകളുടെ തൂക്കം, വിളവ്, ഡ്രൈ മാറ്റർ പ്രൊഡക്ഷൻ എന്നിവയിൽ f_4 മികച്ചതായി നിരീക്ഷിച്ചു. സുമഞ്ജന f_4 രീതിയിൽ മികച്ച കായ്ഫലവും 100 വിത്തുകളുടെ തൂക്കവും വേനലിലും റാബിയിലും രേഖപ്പെടുത്തി. സുമഞ്ജന, ഡി ബി ജി വി-5 എന്നീ ഉഴുന്നിനങ്ങളോടൊപ്പം f_4 കൂടുതൽ വിളവും (1725 കിഗ്രാം/ഹെക്ടർ, 1626 കിഗ്രാം/ഹെക്ടർ) ആദായവും രേഖപ്പെടുത്തി.

ഡി ബി ജി വി 5-ഉം സുമഞ്ജനയും തണലിനെ പ്രതിരോധിക്കുന്ന, മുന്തിയ വളർച്ചയും വിളവും നൽകുന്ന ഉഴുന്നിനങ്ങളായി കണ്ടെത്തി. ഇവ തെങ്ങിൻ തോപ്പിലെ ഇടവിളകൃഷിക്ക് ശുപാർശ ചെയ്യാവുന്നതാണ്. കേരള കാർഷിക സർവകലാശാല ശുപാർശയോടൊപ്പം ഒരു ശതമാനം വീര്യത്തിൽ 19:19:19 വളം, നട്ട് 45 ഉം 60 ഉം ദിവസത്തിനു ശേഷം, നാഫ്ത്തലീൻ അസറ്റിക് ആസിഡ് (എൻ എ എ) 40 മില്ലിഗ്രാമും സാലിസിലിക് ആസിഡ് 100 മില്ലിഗ്രാമും ഒരു ലിറ്ററിന് എന്ന തോതിൽ പൂവിടുന്നതിനു മുൻപും, തുടർന്ന് 15 ദിവസങ്ങൾ കഴിഞ്ഞും പത്രപോഷണമായി നൽകുന്നത് വിളവ് വർദ്ധിപ്പിച്ച് കൂടുതൽ വരുമാനം ഉറപ്പു വരുത്തുന്നതായി പഠനത്തിൽ തെളിഞ്ഞു.